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Renewable energy resources and technologies practice in Bangladesh

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Abstract

Bangladesh has very limited nonrenewable energy resources of its own. She is facing energy crisis and serious desertification problem in rural areas. These issues could be removed if renewable energy is used as a primary source of energy in rural areas. It is essential for scientists and researchers to find out the renewable energy resources and effective technologies. Bangladesh is endowed with vast renewable energy resources such as biomass and solar insolation. Besides, hydro and wind power can be considered as potential renewable energy resources. Harnessing these resources appears to be a promising solution for improving the quality of life of rural villagers. The government and many non-governmental organizations (NGOs) have tried to comprehend and have strived to address the problem of energy. This paper reviews the renewable energy resources and renewable energy technologies (RETs) practicing in Bangladesh in terms of its implementation, research and development activities. The development and trial of systems are mostly funded so far by donor agencies in collaboration with government and NGOs.

Biomass energy sources are traditionally used for domestic cooking and in small rural industries. Approximately 60% of total energy demand of the country is supplied by indigenous biomass based fuels. Activities on the development and promotion of biomass technologies have been going on for one decade. Some national and international funds have been available for biogas technology, improved biomass cookers and production of biomass briquettes. At the time, around 25,000 biogas plants exist all over the country in rural areas and educational institutes, etc. More than 0.20 million improve stoves have been installed to save biomass fuel. Over 900 briquetting machines have been operating in the country on commercial basis.

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The annual solar radiation availability in Bangladesh is as high as 1700 kWh/m^2. Research and demonstration activities carried out for one decade have led to a start of large-scale utilization of PV (solar photovoltaic) by various organizations and by NGOs. More than 61,500 solar PV systems of a total capacity around 3 MW and 260 hot box cookers have been installed all over the country mainly in off-grid rural, hill tracks and coastal Bangladesh.

Kaptai hydroelectric power plant is the only one renewable energy power generation plant of the country that is generating 3.28% of total 3651.20 MW. The first micro hydropower unit of 10 kW has been installed in a village of Bandarban through private initiatives. The project is providing electricity to 140 families in the village and to a Buddhist Temple.

The annual wind speed at a height of 25 m at some coastal locations is above 4 m/s and much higher in the pre-monsoon and monsoon periods. The sites are suitable for power generation, particularly using PV or diesel hybrid technique for winter months.

Keywords: Renewable energy resources; RETs practice; Quality of life; Rural, hill tracks and coastal Bangladesh

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Contents

1. Introduction

1.1. Geographical and other information for Bangladesh

Bangladesh lies in the northeastern part of South Asia between 20°34′ and 26°38′ North latitude and 88°01′ to 92°42′ East longitude with an area of 147,570 km^2 [1] and a population of about 135 million. India surrounds the country in three sides (West, North and East), sharing 3715.18 km of common border. It should be noted here that this is about 93% of Bangladesh's entire land borderlines. The other neighbor being Myanmar, sharing mountainous border in the southeast. The Bay of Bengal lies to the south of Bangladesh. The coastal zone of Bangladesh consists of about 710 km coastline, the largest patch of natural mangrove forest shared with India and a long sea beach along the southeast.

Three major types of landscapes are found in Bangladesh: floodplains (80%), terraces (8%), and hills (12%). Excepting the eastern hilly region, almost all of the country lies in the active delta of three of the world's major rivers: the Ganges, the Brahmaputra, and the Meghna (GBM). The water ecosystem of the country comprises the tributaries and distributaries of these major rivers and numerous perennial and seasonal wetlands like haors, baors and beels. The floodplains of Bangladesh comprise only about 7% of the total area of the GBM catchments, but it discharge about 92% of the flow generated by the GBM system. The ironic fact is that over 80% of the 1.35 trillion m^3 of rainfall runoff occur in the entire GBM catchments during monsoon (June–October), while in the dry period the country suffers from severe moisture stress due to negligible rainfall.

Most of the land area is being used for agriculture, forest and settlement. Very small fraction of the land area is being used to meet industrial and other miscellaneous social and administrative needs. In recent years, however, there is a growing tendency of changing land use from agricultural to other lands, especially to meet the increasing demands for industrial and urban areas. As a result, more and more agricultural lands are being transformed into other lands. Aus, Aman and Boro are the three paddy varieties grown in three cropping seasons: pre-monsoon, monsoon and winter, respectively. Wheat, potato, jute, sugarcane, oilseeds and spices are other important crops grown. The country has a big livestock population, constituted by some 23 million bovine animals, but of very poor quality.

Bangladesh is one of the most densely populated countries. Apart from a few city states, her population density (over 914 persons/km^2) is considered as the most in the world. Its population, however, are dispersed evenly across the country except for the hilly southeastern districts. The growing pressure of increasing population added to the stress on natural resources including land and water. Owing to fertile land, agriculture remained as the major occupation for over 60% of the population for centuries. Over 50% of the agricultural workers do not own any land and get paltry return only to maintain subsistence. Open water fishing is one of the major earning source for a significant

Table 1
National statistics of Bangladesh

Indicators	1991	1995	2003
Population (million)	111.45	119.8	135
Urban population (%)	17.20	22.00	23.10
Population in below poverty level (%)	47	45.8	44.3
Land area (km^2)	147,570	147,570	147,570
Agricultural (%)	55.08	52.06	54.5
Forest (%)	12.80	12.74	17.6
Cultivable wasteland (%)	3.93	4.28	2.1
Current fallow (%)	6.49	2.68	2.6
GDP (US$ in billion)	26.5	32.06	54
Industrial GDP (%)	22.14	24.18	27.80
Services GDP (%)	49.45	50.98	49.37
Agriculture GDP (%)	28.13	24.83	22.83
GDP per capita (US$)	241	336	363
Life expectancy at birth (years)	56	58	64.9
Literacy rate	38.8	43.2	48.8

Ref. [1,2].

proportion of population, especially in monsoon months. The industrial base of the country has remained in its nascent state despite incentives offered by the government. The rate of growth of GDP in Bangladesh has picked up in recent years. During the period 1980–1990, it grew at an average annual rate of 3.7%, barely exceeding the population growth rate; but subsequently, during the period 1999–2004, it exceeded an average annual rate of 5%, to reach about $54 billion in the fiscal year 2003–2004. The per capita GDP is still below the world average of US$ 400. Table 1 gives some of the national statistics of Bangladesh.

1.2. Energy status

Bangladesh's per capita energy consumption is very low, the lowest within the Indian subcontinent. The 2004 energy consumption value stands at 227 kgOE, compared to 500 kgOE for India, 475 kgOE for Pakistan, 400 kgOE for Sri Lanka and 450 kgOE for South Asia, and it was much below the world average of 1680 kgOE. Total primary energy consumption in 2004 was 30.70 MTOE and the energy consumption mix was estimated as: indigenous biomass 60%, indigenous natural gas 27.45%, imported oil 11.89%, imported coal 0.44% and hydro 0.23%. More than 76.9% of the country's population lives in rural areas, meting most of their energy needs (for domestic, commercial, and industrial needs) from traditional biomass fuels. Various marketing companies under the Bangladesh Petroleum Corporation (BPC) distribute kerosene and diesel throughout the country at a uniform tariff rate set by the government. Around 32% have access to electricity, while in rural areas the availability of electricity is only 22%. But the quality of power services in rural areas is very poor; there are reports of frequent voltage fluctuations, unreliable and erratic supply. Only 3–4% of the households have connection of natural gas for cooking purposes. Only about 2–3% households use kerosene for the same purpose and the rest (over 90%) of people depend on biomass for their energy needs [3].

Contribution of biomass in total primary energy consumption of Bangladesh is around 60%. The major sources of traditional biomass are agricultural residues, wood and wood wastes, and animal dung, and their shares in energy supply are approximately 46%, 34% and 20%, respectively. Industrial and commercial use of biomass accounts for 13.7% of total energy consumption. 62.3% of energy required in the industrial sector comes from biomass fuel. Primarily biomass and kerosene are used by majority of the households. Natural gas, LPG, electricity, kerosene and biomass fuels are used for cooking. In areas without natural gas and electricity, biomass is used to meet the household cooking needs. A good amount of bio energy is used for parboiling and space heating. A recent urban household survey estimated that consumption of biomass fuel is 319 kg per capita per year.

Natural gas is currently the only indigenous non-renewable energy resources of the country, which is being produced and consumed in significant quantities since 1970. Gas, the main sources of commercial energy, plays a vital role towards the growth of the economy of Bangladesh. The gas market is dominated by power and fertilizer (using gas as feedstock) sectors, which account for 46.65% and 21.71% of the demand. Composition of the country's natural gas (more than 90% Methane) has been particularly suited for power and fertilizer sector. Government is following a persistent policy to reduce dependence on imported oil and increase the use of indigenous natural gas in meeting the total energy demand of the country. Sector wise consumption of natural gas is given in Table 2.

The cumulative efforts of exploration for oil and gas resources in Bangladesh has resulted in the discovery of 22 gas fields of various sizes, having a total gas initially in place (GIIP) of 28.415 TCF, and initial recoverable reserve of 20.509 TCF. Out of this, about 5.547 TCF has been produced and 14.962 TCF remains up to June 2004.

The utilities responsible for generation of electricity are: (i) Bangladesh Power Development Board (BPDB), which is the largest authority to generate electricity from the conventional sources (like indigenous gas, hydro, diesel, furnace oil) and (ii) Rural Electrification Board (REB), distributing electricity in the rural areas and generating electricity through Independent Power Producers (IPPs). Distribution of electricity to the consumer end is performed by BPDB, Dhaka Electric Supply Authority (DESA), Dhaka Electric Supply Company Ltd. (DESCO) and REB. Up to December 2005 the total installed power plants of the country was 4995 MW. Of the total installed power plants, the effective operational capacity was 4174 MW against the peak demand of about 4100 MW. The maximum generation was 3651.20MW on 22 December 2005. Electricity has been

Table 2
Sector wise consumption (in percentage of total consumption) of natural gas

Year	Electricity generation	Fertilizer production	Industrial use	Commercial use	Cooking	Other uses	Total (MMCM)
1998	46.53	30.14	12.10	1.30	9.50	0.43	7514
1999	48.35	28.42	12.28	1.25	9.34	0.36	8246
2000	46.97	27.38	13.31	1.24	9.54	1.54	8780
2001	49.07	25.36	13.79	1.16	9.17	1.45	9877
2002	51.00	21.62	14.66	1.17	10.09	1.46	10324
2003	46.48	23.94	10.48	1.13	11.18	6.79	11347
2004	46.65	21.71	10.84	1.12	11.52	8.16	12105

Ref. [1].

Table 3
Electricity generation scenario by fuel type (as on 22 December 2005)

Fuel type	Installation capacity		Effective operational capacity		Maximum generation	
	(MW)	(%)	(MW)	(%)	(MW)	(%)
Natural gas	4271	85.51	3666	87.83	3229	88.44
Furnace oil	342	6.85	283	6.78	211	5.78
Hydro	230	4.60	130	3.11	120	3.28
Diesel	151.85	3.04	95	2.28	91.20	2.50
Total	4995	100	4174	100	3651.20	100

Ref. [4].

generating from natural gas since 1970 and from the last two decades it's share being dominating. Generation of electricity from natural gas was 88.44% of total generation by December 2005. Electricity generation scenario by fuel type is presented in Table 3.

Currently, the country has only one coalmine operation project at Barapukuria in Dinajpur district. The project has a target to provide 1.0 million tons of coal per annum from the Barapukuria coalfield. It is planned that 85% of its annual production will be utilized to produce electricity; the rest will be used as fuel for brick making and other purposes. In the fiscal year 2004–2005, 74767.78 metric tons coal has been sold from the field for brick burning. The mining operations may continue up to 70 years from its inception. Bangladesh also has two other coalfields: 1000 million tons at Jamalganj and 450 million tons at Khalaspur. Early estimations suggest that it will not be techno-economically feasible to extract coal from Jamalganj reserve. The country has about 170 million tons of peat reserve in its southern regions. However, recoverable reserve is yet to be determined and the energy resources are not likely to be tapped in near future.

The country use to harness hydropower from one power plant, located in Kaptai. Although the total potential of the resource is about 1000 GWh/year only a part of it is actually being harnessed. The government is contemplating to enhance the capacity of the reservoir and the plant and to produce more power, the feasibility of the enhancement project is underway. In addition, there are two other potential sites from where another 500 GWh/annum of hydroelectricity can be produced. Given the locations, their respective hydro-geological set up, socio-economic, cultural, and environmental considerations, it seems highly unlikely that those potentials could be realized in near future.

1.3. Energy policy

Energy development appears to be a major constraint for continued development of a LDC such as Bangladesh. The major stumbling block is lack in terms of capital investment since energy development programs are highly capital intensive. Traditionally these programs have been implemented with support from the donors and/or multilateral banks. Since independence the government has given adequate priority and about 20% of total public sector investment has been allocated for the development of energy sector. Even then the achievements made in this sector have not been able to cope with the growing demand for energy services, in terms of both quality and quantity. In response to non-cooperation for large-scale investment in energy development by the major donors, which

was fuelled by unacceptably high level of 'system loss' by the major government managed energy utility companies, the government encouraged participation of the private sector in energy development and management program. This was highlighted in the first ever National Energy Policy (NEP), completed and gazetted in 1996 [5]. The NEP recognized that energy plays important roles for socio-economic development of the country and energy development and management should be brought under an integrated policy framework. The NEP set a number of objectives, which are outlined below:

- To provide energy for sustainable economic growth so that the economic development activities of different sectors are not constrained due to shortage of energy.
- To meet the energy needs of different zones of the country and socio-economic groups.
- To ensure optimum development of all the indigenous energy sources.
- To ensure sustainable operation of the energy utilities.
- To ensure rational use of total energy sources.
- To ensure environmentally sound sustainable energy development programs causing minimum damage to environment.
- To encourage public and private sector participation in the development and management of the energy sector.

"National Energy Policy (NEP), 1995" of Bangladesh has got guidelines for Renewable Energy Technologies (RETs). Government has also adopted "Private Power Generation Policy, 1996" for encouraging private sector participation in the electricity generation sector of the country along with BPDB and already several IPPs' are supplying electricity to the national grid. Apart from this, another policy—"Small Power Generation Policy, 1998" has also been introduced to encourage small electricity generation capacity up to 10 MW throughout the country by the private sector. There is no national coordinating agency for Renewable Energy sector in Bangladesh. At present, Power cell is entrusted by the Ministry of Energy and Mineral Resources (MEMR) to foster development of RETs in Bangladesh. A "Draft Renewable Energy Policy" [6] has been submitted by the Power Cell of MEMR that is yet to be approved by the Government of Bangladesh (GOB). Besides, Establishment of Renewable Energy Development Agency (REDA) has been proposed by the National Energy Policy (NEP), 1995 of GOB. In 1998, The Government of Bangladesh lifted import duty and Value Added Tax (VAT) from solar photovoltaic (PV) and wind turbines. Solar PV program of different government bodies (BPDB, LGED, REB) are basically subsidy driven. At present, under the Biogas Pilot Plant project, the Government of Bangladesh gives TK. 7500/= subsidies for a family-size biogas plant which can be used for cooking and lighting purposes.

2. Renewable energy resources and technologies practice

2.1. Biomass resource

Biomass resources include various natural and derived materials mainly categorized as agricultural residues, wood and wood wastes, animal dung, municipal solid wastes.

2.1.1. Agricultural residues

Approximate land use for agriculture is 54.5% and forests is 17.6% of total land area of the country. Agricultural residues contribute significantly to the biomass sector. About 46% of traditional biomass energy is supplied from major crop residues such as rice straw and rice husk from rice plants, bagasse from sugarcane and jute stick. Some amounts of residues produce from wheat, potato, oilseeds, spices, etc. crops grown. Crop residues can be distinguished into field residues and process residues. Field residues are residues that are left in the field after harvesting. They are scattered over a wide area, and are generally used as fertilizer. Process residues are generated during crop processing, e.g. milling. They are available at a central location. The residues from cash crops like groundnut and coconut are also used to provide biomass energy. Jute stick is used for fuel purposes after being used as construction materials.

2.1.2. Wood and wood wastes

Total wood fuel consumption of the country is 8 million m^3 where domestic cooking accounts for estimated 5.1 million m^3 (63%) annually and the industrial and commercial sectors 2.9 million m^3 annually (37%). Besides reserve forest, the homestead trees (including social forest) supplies a significant amount fuel-wood. In fact, most of the fuel-wood consumed by rural households is supplied by the homestead trees, which mainly consist of firewood, twigs and leaves. The trees are supplied as timber to urban and semi-urban areas and to industries. Though it is commonly thought that reserve forests are the main source of wood fuel in the country, but from statistics it has been found that village forests are supplying 70% of total consumption, which has been shown in Table 4. At present there is acute shortages of wood fuel in Bangladesh, due to which poor people opt for other inferior type (not compact, difficult to handle) of biomasses like agricultural residues or animal dung.

2.1.3. Animal dung

Total livestock populations of cattle, buffalo, sheep and goat of Bangladesh in 2000 were estimated as 59.55 million heads. Of the working cattle, 92% was used for cultivation and 0.19% was for transportation [3]. The quantity of dung yield varies from region to region. It was taken as 8–12 kg/animal/day for buffalo, 5–10 kg/animal/day for cattle, 0.25–0.50 kg/animal/day for sheep and goat. About 200 million chickens produce about 0.020 million tons of litter every day. The total dung produced annually was calculated by multiplication of the animal dung production per year and the number of head of different

Table 4
Estimated energy supplied by traditional biomass in thousand tons of coal equivalent

Year	Cattle dung	Jute stick	Rice straw	Rice husk	Bagasse	Fuel wood	Twist and leave	Other waste	Total
1980	1530	466	1498	1713	580	360	1076	891	8114
1985	1670	363	1379	2142	581	435	1270	1053	8893
1990	1866	396	1535	2591	653	425	1325	1096	9887
1995	2018	439	1579	2722	602	529	1325	1183	10399
2000	2441	922	1375	2810	314	1166	1325	1186	11538
2004	2502	922	1418	2854	392	1272	1537	1361	12257

Ref. [1].

animals (FAO) taking the average of the lower and higher dung yield. The number of different livestock heads and their annual production of residues are presented in Table 5. A significant part of the dung is currently being used as fuel. Biogas plant is a better option to use the dung producing both biogas and fertilizer. Poultry litter could similarly be used.

2.1.4. Municipal solid wastes

Total number of city corporations and municipalities in Bangladesh are 4 and 223, respectively. The major sources of municipal solid wastes are households, commercial areas, industries and hospitals. At present around 31 million of the country's people live in the urban areas. In the Fiscal Year of 1997–1998, it was reported that 29,573 manufacturing industries were running all over the country. All most all are in urban areas. Among them about 21,941 industries are producing energy-based organic solid wastes which are categorized in Table 6. Besides according to 2002 estimation, the country has 1342 hospitals giving facility of 45,607 beds, which are mostly in towns. The main cities of the country are already over burdened with solid wastes from different sources. According to the World Banks study, the rural population generates only 0.15 kg per capita per day, while their urban counterparts generate 0.4–0.5 kg per capita per day [7]. All city corporations, responsible for waste management, are unable to handle the solid waste properly.

Table 5
Number of livestock and their residues production in 2000

Livestock type	Heads	Dung yield (kg/animal/day)	Residues (tons/year)
Buffalo	828,000	8–12	3,022,200
Cattle	23,652,000	5–10	64,747,350
Goat	33,800,000	0.25–0.50	4,626,375
Sheep	1,121,000	0.25–0.50	153,436.87
Chicken	200,000,000	0.1	7,300,000
Total			79,849,361.87

Table 6
Organic solid wastes generating industries with their main products

Manufacturing industries	Number	Major products
Food	6076	Fast food, vegetable oil, sugar, dairy, tea, etc.
Tobacco	519	Cigarettes and biddies, etc.
Textile	12,111	Cotton yarn, synthetic yarn, cloth, jute mat and carpet, etc.
Paper and publishing	977	Paper, newsprint, books, newspaper, etc.
Wood products	1134	Hard board, particle board and cork products, etc.
Leather products	313	Footwear, bags, luggage etc.
Furniture (wooden)	460	Varity of wooden furniture
Rubber	173	Cycle tire and tube, and rubber footwear, etc.
Plastic	178	PVC pipe, office and households equipments, etc.
Total	21,941	

Ref. [1].

In the capital city of the country—Dhaka, one of the most populated city in the world with about 10 million inhabitants and area of only 360 km^2, waste disposal system has become one of the major civic project. It has been estimated by different sources that each day about 3000–5000 tons of solid waste materials are generated in the city. Waste Concern, a leading NGO involved in waste management in the country, has entered into a Memorandum of Understanding (MOU) with the Dhaka City Corporation under which eight new community-based composting plants are being established throughout the city. Waste Concern have demonstrated how creative ventures, in which non-government and private sector organizations support the work of waste disposal authorities, can tackle the serious problems of waste management and generate revenue for all those involved. Their innovative approach has been recognized internationally and they are requested to provide technical support in India and Palestine [8].

At present two projects are under active consideration of Ministry of Environment. Two foreign companies (US and Canadian) have submitted their proposal to convert waste into energy in Dhaka using "Plasma Technology". According to Waste Concern, conversion of waste to energy may not be financially viable as our waste has low calorific value and high moisture content. Moreover, our waste has 70–75% organic matter.

A study was done by CGEA-ONYX of France in October 1997 to find out the possibility to install a waste to-energy plant at Dhaka. Average calorific value and density of the solid waste were found to be 3150–3990 kJ/kg and 0.35 ton/m^3, respectively. The estimated daily weight, physical composition and major parts of solid waste of Dhaka city is presented in Table 7.

2.1.5. *Technologies practice for biomass*

2.1.5.1. Improved cooking stoves. In the field of biomass utilization, improved cooking stoves programs have been initiated in most countries of Asia. The programs have been undertaken in China, where 129 million stoves were installed by early 1992 and India, where about 35.2 million stoves were installed by March 2003 [9].

The traditional cook stoves are usually mud-built cylinder with three slightly raised stands on which utensils rest. The efficiency of the stoves for biomass fuel is between 5% and 10%, emitting greenhouse gases, have risk of firing, create health hazard in kitchen.

Table 7
Daily amount of solid waste in Dhaka city with physical composition and major parts

Amount of solid wastes		Physical composition		Major parts in wastes	
Source	Tons	Material	Weight (%)	Parts	Weight (%)
Household	1400	Paper	10.0	Moisture	45.00
Commercial	600	Glass	1.4	Combustible	20.00
Industrial	800	Metal	0.5	Incombustible	34.70
Medical	200	Plastic	2.6	Others	Rest
		Textile	2.5		
		Wood/grass	22.0		
		Ash/soil	40.0		
		Food waste	18.0		
		Others	3.0		
		Total	100		

Institute of Fuel Research and Development (IFRD) of Bangladesh Council of Science and Industrial Research (BCSIR) has been carrying out research on improved stoves for a long time. Their improved household stove is claimed to save 40–60% fuel compared to traditional ones. There are about 0.2 million improved stoves in operation, but they are not being regularly used. A strong drive is required to use improved household stoves. Forest Department is planning to build one million stoves for households living in the forest area. Government has also similar plans for other rural households.

2.1.5.2. Biogas plant. Biogas production is well established in China and India. In China, there are about 550 million household digesters and 2360 biogas stations. The number of family size biogas digesters in India is about 3.5 million [7]. An agriculture-based country like Bangladesh has huge potentials for utilizing biogas technologies. Animal dung available from 24.48 million cattle and buffalo are nearly 185.67 million kg per day (in Table 5). One kg of dung can produce 0.037 m^3 of biogas. According to an estimate available cattle dung can produce 2.50 billion m^3 of gas that is equivalent to 1.28 million tons of kerosene or 2.56 million tons of coal. Besides, a substantial amount of biogas can be produced from poultry dropping, waste, marine plants, garbage and water hyacinth. If each family of Bangladesh can be associated with a biogas plant, then only human excreta will give about 10 billion m^3 biogas. At present Bangladesh meet 46% of its energy need by agricultural residue, 10% by fuel wood and 24% by tree residue. Biogas will reduce energy deficit 15%. According to IFRD, there is potential of about four million biogas plants in our country.

More than 25,000 biogas plants (mostly of fixed dome type) mostly by IFRD using mainly cow dung have been installed for households. Institutional and commercial biogas plants have now been constructed by various agencies especially LGED, using cow dung, poultry dropping or even human excreta. There is a huge potential for biogas production from municipal and other industrial wastes. About 75% of the IFRD biogas plants are cow dung based, 20% based on poultry waste and 5% based on other biomass (kitchen waste, human excreta, water hyacinth, duck weed and other bio-waste). Summary of biogas plant installation by different organization is presented in Table 8.

Recently the Netherlands Development Corporation is starting a national program to set up 36,450 biogas plants by 2009. GTZ in collaboration with BCAS has recently

Table 8
Summary of biogas plant installation by different organization in Bangladesh

Organizations	Type of systems installation	Number	Capacity (cft/day)
LGED	Family biogas plant	1164	120–420
	Community biogas plant	02	Up to 2000
IFRD of BCSIR	Phase-I	4664	100–200
	Phase-II	17194	120–420
BRAC	Family biogas plant	1200	120–420
	Power generating unit	02	Each of 800 Wp
Grameen Shakti	Family biogas plant	300	120–420
Proshika and others	Family biogas plant	476	120–420
Total		25,000	

completed a feasibility study to promote biogas plants in commercial poultry farms. The study findings are:

- Over 25,000 fixed dome biogas plants have been installed in Bangladesh.
- There are already more than 2000 poultry-based biogas plants.
- Poultry farms are emitting bad smell, biogas technology is a solution.
- Presently, litter is sun dried and sold at low price.
- Slurry is a good fertilizer, it is sold at prices between 0.7–3 TK/kg.
- Biogas is being sold at the rate of TK. 300/ = per connection.
- Some large farms are producing electricity, but experience problems with moisture and hydrogen sulfide.
- The technology is still not widely known.

It appears that poultry biogas plants of moderate and larger sizes are financially viable. For heat purposes moderate size farm is suitable. Larger size farms could also produce electricity. Such studies should be undertaken in commercial biogas plants based on livestock and other wastes. There is a huge potential for commercial biogas plant for other uses.

2.1.5.3. Biomass briquetting. Biomass briquetting is now an established technology with local manufacturing capability in a number of Asian countries, e.g. Japan, Korea, Taiwan, China, India, Thailand, Bangladesh and Malaysia. The number of briquetting machines appear to be operating in China is about 600. The biggest briquetting plant is in Malaysia. Briquette is a block of condensed biomass with increased volumetric calorific value for use as fuel. Such briquettes are comparable to woody biomass (with high ash content) and quite stable with long self-life. Different types of biomass like rice straw or rice husk, sawdust, wheat husk, jute stick and bagasse can be used, but at present, mostly rice husk is used as raw materials. After successful researches on briquette production, they are now available commercially. Most of them are heated-die screw-press type.

Briquetting is an old concept that was first patented in 1864 in USA. In Bangladesh the activities on the subject started in early 1980s by importing two machines from abroad. The commercially used machine is of heated die screw press type and raw materials used are mainly rice-husk and sawdust. In a robust calculation it is found that more than 15,000 briquette machines can run with the existing bio residues but at present only about 906 machines are working in Bangladesh [10]. Distribution of briquetting machine in different greater districts of Bangladesh is listed in Table 9.

Recently BRRI has made briquettes from rice husk and use them as fuel for heating purposes in their laboratory and got 20% better efficiency. They plan to use them in various rice mills for parboiling.

2.1.5.4. Gasification and, pyrolysis of organic solid wastes. Another established biomass energy technology in Asia is gasification. The biggest gasifier program has been undertaken in India where about 17,000 power gasifiers corresponding to a capacity of 24 MW gasifiers were installed by the end of 1995–1996. In China, the total number of installed gasifier sets is about 800 at present. Networks of producer gas supply has been reported to exist in Shandong and Hubei provinces of China. The gasifiers use agricultural and forest residues and one gasifier can supply 100 households with gas for cooking and space heating [11].

Table 9
Distribution of briquetting machine in different greater districts of Bangladesh

Greater district	Number of machine	Number of foreign machine
Sylhet	23	15
Khulna	174	2
Chittagong	135	—
Rajshahi	268	—
Barisal	32	—
Dhaka	47	—
Total	889	17

There has been no work on biomass gasification in Bangladesh. A demonstration biomass gasification plant of 200 kW based on rice husk is being set up by LGED at Dinajpur. Another 250 kW commercial power plant, also based on rice husk, is planned to be set up by a private entrepreneur in Kapasia, with assistance from IDCOL.

Besides, feasibility study of pyrolysis for production of alternative liquid fuel from organic solid wastes (scrape tyre, waste plastic, municipal solid wastes and lignocellulosic materials) may be carried out in Bangladesh. Some research work in the field has been continuing in Rajshahi University of Engineering and Technology (RUET) since 2000. Pioneer research works has also been running in the neighbor countries: India, China and Malaysia.

As for bio-fuel, a joint venture between a local company (NITOL MOTORS) and two Singapore firms have recently been signed to invest $ 4.5 million to manufacture 12,000 l of ethanol from molasses from the Sugar Mills of North Bengal. It will be mixed with normal petrol/octane in the ratio of 23:77 to be produce ‘gasohol’ to run motor vehicles. The price of ‘gasohol’ will be 20–30% lower than conventional petrol.

2.1.6. Research and development activities in the field of biomass

Recently research and development works in the field of RETs for biomass energy have initiated in some government and non-government organizations and educational institutions with the aid of domestic and international funds. The R&D activities are summarized in Table 10.

2.1.7. Organizations and their activities for overall development of RETs for biomass

Summary of the several attempts that have been taken up by some of the government organizations, NGOs and international organizations for overall development of the biomass energy technologies are presented in the following sections.

2.1.7.1. Projects by government organizations.

1. *Biogas pilot plant project of IFRD:* IFRD launched its journey as the fuel research division of the East Regional Laboratory, Dhaka in 1954. After the independence of the country it was renamed as Fuel Division of BCSIR Laboratories, Dhaka. IFRD was established as a separate institute of BCSIR in 1980. The objectives of the institute are:
   - To develop the RETs for utilizing the existing traditional and commercial fuels more efficiently.

Table 10
Summary of R&D activities in the field of RETs for biomass energy

RETs	Organizations	Activities
Improved stoves	IFRD of BCSIR	Several designs have been developed at IFRD in three basic categories: without chimney, with chimney, and with waste heat utilization
Biogas plants	IFRD of BCSIR, LGED, BAU	Fixed-dome type plants are found to be more suitable for local conditions and disseminated with government subsidy of Taka 7500. R&D activities of Bangladesh Agriculture University (BAU) dominate in this field
Briquetting machines	KUET, BRRI	Under the "RETs in Asia" program, Khulna University of Engineering & Technology (KUET) is developing better machines with longer screw life
Pyrolysis technology	RUET	Research and development works for pyrolysis of locally available organic solid wastes for production of alternative liquid fuel has been continuing in Rajshahi University of Engineering and Technology (RUET) since 2000

Ref. [12].

- To assess the rapid production of biomass and fast growing trees for its utilization as fuel.
- To find better utilization of biomass and other organic wastes for production of biogas and its utilization for generation of electricity.
- To develop RETs for utilization of solar, wind and hydropower.
- To produce different petrochemicals from natural gas.
- To study the environmental pollution caused by the emission from automobiles and industries.

  The Biogas Pilot Plant Project has been implementing by the IFRD since 1995. Under the first phase (duration: 1995–2000) of the project up to June 2000, 4664 biogas plants were constructed. Under the second phase (duration: 2000–2004) of the project 17,194 biogas plants have been constructed allover the country. According to an assessment report it has been seen that 99% of the plants installed under the project are in operation and 91% of the owners could meet their household fuel demand from the plants [13].

2. *Biogas project of Local Government Engineering Department (LGED):* LGED is playing a pivotal role in rural infrastructure development. People at large in rural Bangladesh are now enjoying the benefits of LGED's different rural development projects. Rural infrastructure development projects undertaken by LGED are contributing a great deal towards the socio-economic development in the country along with the development of communication and market networks. Various activities under different projects have been creating short- and long-term employment opportunities for the poverty-stricken people. LGED is implementing biogas project for wide-scale dissemination of the technology. LGED has already installed 1166 biogas plant of different types from diversified substrates including cow dung, hyacinth, human excreta.

2.1.7.2. RETs program by NGOs and private sector.

1. *Biogas program of Bangladesh Rural Advancement Committee (BRAC):* BRAC was established as a relief organization in 1972 after liberation war. It has evolved into country's largest NGO with its objectives of "alleviation of poverty and employment of poor". Its wide range of programs and projects in areas including education, health care, agriculture, poultry, craft, dairy and micro-credit banking are dispersed throughout the country. BRAC started it's Renewable Energy Program for overall development of RETs in remote locations. Under this program 1200 biogas plants have already installed in different districts. BRAC has a future plan to install 50,000 biogas plants [14].
2. *Biogas program of Grameen Shakti (GS):* GS was established in 1996 to develop and popularize renewable energy resources. GS has been appreciated globally for it's outstanding approach of "micro-credit" for delivering solar home systems (SHSs) in rural areas. GS expects not only to supply renewable energy services, but also to create employment and income-generation opportunities in rural Bangladesh. GS has installed 300 biogas plants allover the country. GS has got loan and grant from different bilateral and multilateral development partners including GEF, IFC, USAID, SIDA, etc. [15].

2.1.7.3. Bilateral and multilateral development partner assisted projects.

1. *Sustainable Rural Energy* (SRE) *project of LGED:* SRE has been conceived by LGED, a component of Sustainable Environment Management Program (SEMP), a project of Ministry of Environment and Forest funded by UNDP. The twin objectives of SRE component under SEMP are technology demonstration and technology transfer in the field of renewable energy in Bangladesh. Considering the natural resource base and socio-economic condition, SRE project has considered four potential renewable energy sources in Bangladesh to deal with: Solar, biomass, wind, and micro-hydro.

   The overall objectives of SRE are to explore opportunities for community-based renewable energy options for different applications and its multipurpose use in off-grid areas of Bangladesh. Component activities of SRE are grouped into three major categories:
   - Demonstration of diversified applications of RETs.
   - Capacity building through training on RETs.
   - Development of Renewable Energy Information Network (REIN) in Bangladesh.

     Under SRE project LGED is implementing the following three-biomass energy development project
     1. *Electricity generation from poultry wastes:* LGED have installed an electricity generation unit from poultry waste at Faridpur Orphanage Institute. Total number of birds of the poultry firm is 5000. Mission has planned to increase the number up to 20,000 in the future. Installed power generation at present is 4 kW, to be increased up to 10 kW. If successful, this project could be replicated throughout the country and contribute significantly to our energy sector.
     2. *Community-based biogas plant:* In order to support LGED's movement on biogas technology, SRE project has taken up a pilot scheme on community-based biogas plant in a more comprehensive way aiming at overall improvement of health and sanitation of the community. The demonstration plant is now under

implementation at Talihati union under Nikli Upozila in Kishoregonj district and a total of 150 families covering the whole community would be benefited. All the families in the community have been provided with improved sanitary latrines, which are connected with a central digester. Once completed, the demonstration plant would benefit the community in many ways: providing energy for cooking and thereby saving fuel wood, ensuring better health and sanitation of the community and also producing good quality pathogen-free fertilizer for agriculture use.

3. *Community biogas plant for educational institute:* One of the demonstration plants of LGED is now under implementation at Zakaria educational institute at Senhati industrial area under Digholia upazila in Khulna district. This locality is a very high-density population. Most of them are from different part of the country and working in the industry surroundings. Four hundred peoples altogether with students, teaching staff and their families are living in this compound. The madrasa owns a market of 60 shops. All of them brought to the better sanitation system. Three latrines open for public use, which develop sense of hygienic sanitation; and increase quantity of biomass that produces more gas for cooking. It might be the best way to disseminate this technology among the people surroundings working in the industries from various part of the country.

   As one of the objectives of SRE project, LGED has also developed the "Renewable Energy Information Network (REIN)", with a comprehensive scope for developing an information platform for RETs. This network will be designed and tailored to facilitate the energy planners, project developers, researchers and all relevant organizations in developing RET projects and promotion of renewable energy utilization in Bangladesh [16].

2. *RETs in Asia program:* RETs in Asia is a research and dissemination program funded by the Swedish International Development Cooperation Agency (SIDA) and coordinated by the Asian Institute of Technology (AIT), Bangkok. The first phase of the regional program (RETs in Asia I) was carried out over a 2-year period during 1996–1998, while the second 3-year phase (RETs in Asia II) started in January 1999. Basically, RETs in Asia is a Regional Research and Dissemination Program which is to promote the diffusion of selected mature or nearly mature RETs through twelve national research institutions (NRIs) of six Asian countries: Bangladesh, Cambodia, Lao PDR, Nepal, Philippines and Vietnam. The first phase of the program covered three RETs: photovoltaic, solar drying and biomass briquetting and briquette stoves. The main objectives of the second phase of the program are as follows:
   - To conduct applied technical research to adapt RETs to local conditions in selected Asian countries with weak science and technology infrastructure.
   - To innovate and implement mechanisms for disseminating RETs in the selected countries.
   - To train entrepreneurs and technical personnel with the aim of disseminating RETs.
   - To disseminate the results of the program among policymakers, with a view to making an impact on the policy process.

The research and development activities on briquetting have been continuing by the financial assistance of SIDA through technical by AIT under RETs in Asia program in KUET science 1997. After successful operation of Phase-I of RETs in Asia program,

Phase-II started in 1999. The main objective of Phase-II program was to develop an improved briquetting system, which includes a machine to produce briquette and a stove to burn it efficiently.

2.2. Solar energy

Bangladesh is situated between 20°34′–26°38′ degrees north latitude and 88°01′–92°41′ degrees east, which is an ideal location for solar energy utilization. Daily average solar radiation varies between 4 and 6.5 kWh/m^2. Maximum amount of radiation is available on the month of March–April and minimum on December–January. Different R&D Organizations, Institutes and Universities are collecting solar insolation at different parts of Bangladesh. Solar insolation data can be found from the following sources:

- Renewable Energy Research Centre (RERC), Dhaka University is the only source that has got long-term measured data of Dhaka city in Bangladesh. The published data are average of results of hourly measurements of over 3 years global and diffuse radiation with Eppley Precision Pyranometer.
- Bangladesh Meteorological Department has 34 sunshine recording stations situated generally in towns and cities.
- Department of Mechanical Engineering, Bangladesh University of Engineering and Technology, has also got time series data of Dhaka city.

Apart from the above-mentioned sources, few other organizations or institutes have also measured time series of global radiation, direct or beam radiation, diffuse radiation, sunshine hours and temperatures of different parts of the country. Monthly Global Solar Insolation at different cities of Bangladesh and Daily Average Bright Sunshine hour at Dhaka city are presented in Tables 11 and 12, respectively.

Table 11
Monthly average global solar insolation (in kWh/m^2/day) at different cities of Bangladesh

Month	Dhaka	Rajshahi	Sylhet	Bogra	Barisal	Jessore
January	4.03	3.96	4.00	4.01	4.17	4.25
February	4.78	4.47	4.63	4.69	4.81	4.85
March	5.33	5.88	5.20	5.68	5.30	4.50
April	5.71	6.24	5.24	5.87	5.94	6.23
May	5.71	6.17	5.37	6.02	5.75	6.09
June	4.80	5.25	4.53	5.26	4.39	5.12
July	4.41	4.79	4.14	4.34	4.20	4.81
August	4.82	5.16	4.56	4.84	4.42	4.93
September	4.41	4.96	4.07	4.67	4.48	4.57
October	4.61	4.88	4.61	4.65	4.71	4.68
November	4.27	4.42	4.32	4.35	4.35	4.24
December	3.92	3.82	3.85	3.87	3.95	3.97
Average	4.73	5.00	4.54	4.85	4.71	4.85

Ref. [17].; Recording period: 1988–1998.

Table 12
Daily average bright sunshine hour at Dhaka city

Month	Daily mean	Maximum	Minimum
January	8.7	9.9	7.5
February	9.1	10.7	7.7
March	8.8	10.1	7.5
April	8.9	10.2	7.8
May	8.2	9.7	5.7
June	4.9	7.3	3.8
July	5.1	6.7	2.6
August	5.8	7.1	4.1
September	6.0	8.5	4.8
October	7.6	9.2	6.5
November	8.6	9.9	7.0
December	8.9	10.2	7.4
Average	7.55	9.13	6.03

Ref. [16]; Recording period: 1961–1980.

2.2.1. Technologies practice for solar energy

2.2.1.1. Solar photovoltaic (PV). The role of PV generated electricity for various applications ranging from water pumping, domestic supply, street lighting, telecommunication networks and navigational aids has increased tremendously over the last few years as the cost of the module has dropped dramatically making it competitive with conventional systems in some locations. The success of this technology in Asia is even more remarkable due to the fact that most homes are still not connected to the national grids.

In China, the research and development in PV technology started in 1958. The 12 production lines in the country have a total capacity of about 5.5 MWp and produces annually about 1 MW capacity modules of which about a third is exported. PV power is used for water pumping, microwave relay, railway signal and PV home electric systems for lighting and TV. The solar PV program was initiated in India in 1975 and during the Eighth Five Year Plan, (1992–1997) PV program has been allocated Rs 900 million (about 10% of the entire renewable energy budget). It has indigenously developed technology and production facilities. India is the second largest crystalline silicone manufacturer in the world with an annual manufacturing capacity of 8.5 MW. In India, there are total 50 companies involved in PV. The telecommunications sector of the government is the major user of PV with over 5.5 MW of purchases in 1995.

Despite of large potential of solar system in Bangladesh, utilization of solar energy has been limited to traditional uses such as crop and fish drying in the open sun. Solar PV are gaining acceptance for providing electricity to households and small businesses in rural areas. In 1988, Bangladesh Atomic Energy Commission (BAEC) installed several pilot PV systems. The first significant PV-based rural electrification program was the Norshingdi project initiated with financial support from France. Three Battery charging stations with a total capacity of 29.4 kWp and a number of stand alone SHSs with a total capacity of 32.58 kWp were installed. REB owned the systems and the users paid a monthly fee for the services. Since 1996, penetration of SHSs increased rapidly, mainly due to the efforts of

GS, which sells PV systems on credit to rural households through its extensive network. Several other NGOs such as CMES and BRAC are also engaged in promoting PV technology. PV modules are generally imported, while there are a few private companies manufacturing PV accessories [15].

According to a World Bank-funded market survey, there is an existing market size of 0.5 million households for SHSs on a fee-for-service basis in the off grid areas of Bangladesh. This assessment is based on current expenditure levels on fuel for lighting and battery charging being substituted by SHSs. Also it has been observed that in most developing countries, households typically spend not more than 5% of their income on lighting and use of small appliances. By this measure, about 4.8 million rural Bangladeshi households could pay for a SHS [18].

At present the national grid is serving only 50% of the nearly 10,000 rural markets and commercial centers in the country, which are excellent market for centralized solar photovoltaic plants. Currently private diesel genset operators are serving in most of the off-grid rural markets and it has been found that 82% of them are also interested in marketing SHSs in surrounding areas if some sorts of favorable financing arrangements are available [19]. Summary of installation of solar PV systems by different organizations in Bangladesh is shown in Table 13.

2.2.1.2. Solar thermal technologies. The solar thermal technologies that are of interest in Asia are solar hot water systems, solar dryers and solar cookers. Many countries in the region have developed domestic solar water heaters (DSWHs) and sell them commercially, while even Australian, European and American models are also available in a few countries. The DSWHs are usually the thermosyphon type with a collector area of about $2\,m^2$ and a storage tank of about 200 l. Some countries have a strong program in this technology with government-aided incentives and other financial aids promoting the growth of this technology.

In India, solar water heater of about 0.7 million m^2 of collector area have been installed [9]. There are around 61 units of solar dryers and 10,000 units of solar desalination systems. By the end of 1996, 55 small manufacturers of solar cookers have sold around 422,000 units. An Integrated Solar Combined Cycle Power Plant (140 MW) with a Solar Power Generating System of 35 MW is in the inception stage of development in Rajasthan [20]. Fiscal incentives like exemption of customs duty, central sales tax and depreciation under income tax are provided, while the monetary incentive of Rs $1000/m^2$ of collector area is also given. It is, therefore, interesting to note that about 250,000 m^2 of collector area has been for industrial systems, while only about 40,000 m^2 of collector area was in the domestic sector [21].

In China, commercialization of DSWHs have gone a long way with more than 100 small factories involved with a production capacity of more than 1 million m^2 of collector area per year. It is estimated that the total installed collector area is more than 5 million m^2 [22]. Though the government of China initiated the development and propagation of solar cookers during the early 1970s, much could not be achieved until recently. China now has around 140,000 units of solar cookers in operation.

Although R&D activities show viability of solar thermal devices, these have not found applications in the public or private sector. While solar water heaters for hotels and hospitals could bring down electrical loads, solar cookers should conserve biomass and solar dryers would be useful for drying timber, paddy, fruits and vegetables with benign

Table 13
Summary of installation of solar PV systems by different organizations

Name of organizations	Number installions and locations	Capacity (kWp)
Government organization		
Local Government Engineering Department (LGED)	A number of SHSs in coastal cyclone shelters in coastal districts	19.6
	1 SHS in Tribal community center at Khagrachari and 1PV water pump in Prantik lake at Bandarban	0.45
	151 SHSs, 9 centralized units, and 1 water pump in remote off-grid areas allover the country	33.8
Semi-Government/Autonomous organizations		
Bangladesh Council of Scientific and Industrial Research (BCSIR)	16 SHSs, 1 pump, 2 solar data logging units (only for research).	1.5
Bangladesh Power Development Board (BPDB)	300 SHSs, and 4 centralized units at Juraichari, Rangamati	54
Rural Electrification Board (REB)	1272 SHSs allover the country	72.75
Non-Governments organizations		
Grameen Shakti	42,119 SHSs all over the country	2151.02
Bangladesh Rural Advancement Committee (BRAC)	10,456 SHSs all over the country	300.545
Thangamara Mohila Sobuj Shangha (TMSS)	762 SHLSs	42.80
Center for Mass Education in Science (CMES)	796 SHLSs	39.80
ANANDO	35 SHLSs	3.75
Coast Trust	532 SHLSs	26.60
Integrated Development Foundation	601 SHLSs	30.05
Srizony Bangladesh	1710 SHLSs	85.50
SHUBASHATI	592 SHLSs	29.60
Private companies		
Singer Bangladesh Ltd.	31 SHLSs	1.55
SIEMENS Bangladesh Ltd.	1000 SHLSs and 5 centralized units	51.26
Micro Electronics Ltd.	700 SHSs	39.31
First Bangladesh Technologies Ltd. (FBT)	93 SHSs	4.035
Bangladesh Center for Advanced Studies (BCAS)	5 Solar Health Care	2.265
UBOMUS	400 SHSs	20
Total = 61567 SHSs/SHLSs, 18 Centralized units, 5 Solar health center, Solar costal cyclone shelters and 3 water pumps.	3010.185 kWp (= 3.01 MW)	

environmental effects. Only BRAC has propagated this technology in the field by installing 260 Hot Box cookers. The NGO has a future plan to install more 5000 Hot Box cookers allover the country. Some of the organizations of the country (in Table 14) have been continuing R&D activities in the field of solar thermal technologies. Suitable incentives are essential to make such applications attractive. Suitable policies and mechanisms are yet to be developed for increasing efficiency of every use in different sectors.

Table 14
Summary of R&D activities in the field of solar energy technologies in Bangladesh

RETs	Organizations	Activities
Solar PV balance of systems	Garmeen Shakti, CMES, IFRD	Local manufacturing of all balance of system components (like charge controller, cable, inverter, converter, etc.) possible
Solar water heaters	RERC, IFRD and CMES	Manufacturing with local design and fabrication facility possible
Solar cooker—parabolic	IFRD and ANANDO	IFRD has successfully field-tested its design that can quickly boil water on clear sunny days. Such solar cookers are now on sale at a cost of TK 580.00 (US$ 9.00) at IFRD. ANANDO is also manufacturing and marketing it′s products with imported materials and design
Solar cooker—box type	IFRD and CMES	IFRD′s design is made of locally available raw materials. The manufacturing costs of such a cooker is about TK 1000 (US$ 16.00) excluding the cost of utensils. The cookers are now being sold at IFRD
Solar dryer	IFRD, BRRI and BAU	Different types have been designed and tested with locally available materials
Solar wood seasoning plant	BFRI	A simple, inexpensive and effective solar kiln has been developed for seasoning timber using solar radiation in Bangladesh Forest Research Institute (BFRI). The kiln can be constructed conveniently with locally available materials. Timbers of different species and dimensions can be seasoned throughout the year in the solar kiln
Solar passive architecture	BCSIR	A solar house has been designed and built in the BCSIR Campus, the purpose is to keep the house warm in winter and cool in summer

Ref. [12].

2.2.2. R&D activities in the field of solar energy

There are seven public Technical Universities and three large research centers in Bangladesh, where feasibility studies and innovative research works in the field of RETs may be carried out for available renewable energy resources. They have technically sound human resource but lack of sufficient financial support. Some R&D activities in various fields of RETs have been carrying out in these Universities, research centers and in some NGOs. These are summarized in Table 14.

2.2.3. Organizations and their activities for the development of RETs for solar energy

Summary of the several attempts by some of the government organizations, NGOs and international organizations for overall development of the solar energy technologies are presented in the subsequent sections.

2.2.3.1. Projects by government organizations.

1. *Cyclone shelter solar electrification project of LGED:* Through JICA-assisted cyclone shelter project, LGED has installed 19.65 kWp (17.01 kWp for SHSs and 2.64 kWp for

street light) of solar PV systems in several cyclone shelters in coastal districts of Bangladesh. In each of the cyclone shelters, the solar installations have been designed to operate 18 lamps and one TV.

2. *Chittagong hill tracts solar electrification project of BPDB:* BPDB, established in 1972, is responsible for planning, construction and operation of power generation and transmission facilities throughout Bangladesh and for distribution in urban areas except Dhaka and its adjoining areas. Total installed capacity of BPDB is 4995 MW (including 302 MW generated by Independent Power Producers). BPDB generates electricity from both the renewable (hydro) and non-renewable sources (natural gas, furnace oil, diesel etc.). There are some places where solar PV is used for supplying electricity to lighting and communication equipment. But the present coverage is as low as 16%.

   Engineers of BPDB have conducted a "Feasibility Study for Solar PV in Chittagong Hill Tracts Region" and currently implementing Solar PV Project at three upazilas in the Chittagong Hill Tracts region where different types of solar PV applications including SHSs, water pumps, vaccine refrigerators, street lamps, centralize power station, etc. Up to January 2005, BPDB installed solar PV systems of total capacity 54 kWp at Juraichari upazila: 10.8 kWp for centralized system and 7.2 kWp for street light and rest 36 kWp for 300 SHSs (ranging 75–120 Wp). Another two remote upazila Beliachari and Barkol will also be under solar electrification by providing 1800 SHSs. BPDB expected to installed of total capacity around 150 kWp in Chittagong Hill Tracts Region. The overall charge of supervision and bill collection of different systems will be done by the Beneficiary Management Committee composed by the local people [4].

3. *RETs projects of REB:*
   - *Diffusion of RETs project by REB:* The Bangladesh Rural Electrification Program was founded with a Presidential Ordinance in October 1977 that established the REB as the semi-autonomous government agency reporting to the Ministry of Power Energy and Minerals Resources. Which was responsible for electrifying rural Bangladesh. Since its inception, the purpose of the program has been to use electricity as a means of creating opportunities for improving agricultural production and enhancing socio-economic development in rural areas, whereby there would be improvements in the standard of living and quality of life for the rural people.

     Under the first phase of the project (1993/1994–1997/1998), a "Renewable Energy" cell of REB has implemented the first semi-commercial 62 kWp Solar PV Project and installed 5 SHSs (ranging 50–92 Wp) of capacity 370 Wp. In the second phase of the project (2002/2003–2005/2006), REB has been able to install 605 SHSs (ranging 50–100 Wp) a total of capacity 36.11 kWp allover the country by February 2006 [23].
   - *Rural electrification through solar energy (IDA) project of REB:* The project has been taken up by REB in the FY 2002/2003 and it will be continued up to FY 2006/2007. Under this project, REB has already installed 662 SHSs (ranging 36–92 Wp) a total of capacity 36.27 kWp allover the country by February 2006 [23].

4. *Feasibility study on R&D on RETs by IFRD:* Recently a project on the "Feasibility Study on R&D of Renewable Energy (Solar, Wind, Micro-Mini Hydro)" has been undertaken by the IFRD of BCSIR. The aim of the project is to generate data and information to study the possibility of natural solar, wind and micro hydropower applications in Bangladesh either for water pumping or for generation of electricity particularly in remote and off-shore islands. The small industries may find solar, wind

and micro hydropower prospective in remote rural areas or in the islands and coastal region. Acquired technical knowledge from this project will be helpful to develop new technologies in the field of solar, wind and micro hydro, so that the quality of life of the people of coastal, off-shore islands, hilly and other remote rural areas can be improved significantly. IFRD has established a laboratory for conducting research and testing on solar, wind and micro-hydro equipment. Solar energy component of the program have been collected solar data (insolation, temperature and humidity) for three: Dhaka, Tecknaf and Sailo propat in Bandarban district.

2.2.3.2. Projects by private sector and NGOs.

1. *Solar energy programs of GS:* Up to June 2005 GS has installed 42,119 SHSs in 14 districts of Bangladesh. Over the next 2 years, GS intends to install 20 small battery-charging stations, 20 computer training centers and 20 multi-service centers, all powered by solar energy [15].
2. *Dissemination program of Center for Mass Education in Science (CMES):* CMES was created in 1978 with an aim to take science and technology to the common people of the country. Later on CMES started solar energy related activities in the distant areas of the country through its field offices. It has carried R&D activities on solar cookers, solar water heaters, solar dryers, SHSs, etc. It has recently established its "Solar Lab" to take up adaptive research on accessories of solar PV systems, such as tube light ballasts, charge controllers, inverters, income generating appliances like sewing machines, drilling machines, etc. It has installed 796 SHSs under Rural Electrification and Renewable Energy Development Project (REREDP) of IDCOL. At present, CMES is one of the country's focal agencies in the "RETs in Asia Program" [24].
3. *Renewable energy program of BRAC:* Under this program BRAC has installed 10,456 SHSs by May 2005 and 260 Hot Box cookers. It has also installed 2 grid-interactive PV systems and 6 PV-Wind hybrid systems. The program involved installing PV systems in its branch offices (training centers, schools, health clinics) and micro-enterprise projects (carpentry, tailoring shop, cloth dyeing, etc.) and in government-owned buildings (rest houses, cyclone shelters, weather-monitoring stations). BRAC has a future plan to install 100,000 SHSs, 5000 Hot Box cookers and a solar energy research institute [14].

2.2.3.3. Bilateral and multilateral development partner-assisted projects.

1. *SRE project of LGED:* Considering the natural resource base and socio-economic condition, the SRE project has also considered solar energy with other three potential renewable energy sources in Bangladesh: biomass, wind and micro-hydro. Under this project LGED has installed 151 SHSs, 9 centralized PV systems and 1 PV water pumping unit of a total capacity 33.80 kWp [16].
2. "*Opportunity for women in RET utilization in Bangladesh*" *project by PSL:* This pioneering project was initiated in September 1999 with funding from ESMAP as an effort towards demonstrating the capability of rural women from developing countries in engaging as clean energy service providers for their community. Rural women are already the largest users of renewable energy, by virtue of using biomass fuel for cooking, yet their role in modern energy utilization is usually overlooked. This project was designed with a vision that allows the role of rural women to be enhanced by

extending their participation in technology-based activities. The project location is Char Montaz, an island with 2000 households, in the southern coastal region of Golachipa Thana of Bangladesh. Thirty-five rural women of Char Montaz are engaged in the operation of a micro-enterprise for construction and sale of DC lamps, which can be used in combination with batteries in SHSs. With continued training from this project, the women learnt lamp construction with quality control, business development and marketing. More than 1000 lamps are being used with re-chargeable batteries for lighting the rural houses, shops, mosques and fishing boats. As a significant contribution, this activity has removed some of the social and cultural discrimination associated with the gender role to be played by women, an opportunity aimed towards poverty alleviation. Overall impact to be achieved from this project has far-reaching potential not limited to the direct participants only, since the benefit of improved environment extends with every new household that adopts modern lighting.

The project has entered its second Phase in 2002 where the objective is to

- Expand the scope of income generation for women. In addition to on-going DC lamp assembly, enhance the manufacturing capacity to assemble state-of-the-art charge controllers for SHSs for the upcoming national projects.
- Expand the market for off-grid DC lamp and battery service to a larger area so that more rural people can experience the benefit of modern lighting.
- Demonstrate financial viability of solar electrification service for dispersed households that are too distant for grid and micro-grid alternatives.

3. *Solar and Wind Energy Resource Assessment* (*SWERA*) *project:* In most of the developing countries, renewable resource information is absent or inadequate. This is one of the major barriers for widespread deployment of RETs in these countries. Understanding this obstacle, UNEP is carrying out a 3-year (June 2001–July 2004) long "SWERA" project with GEF fund. SWERA will start with the following countries—China, Bangladesh, Sri Lanka, Nepal, Ghana, Kenya, Cuba, Honduras, El Salvador, Nicaragua, Algeria, Brazil and Guatemala. The overall goal of this project is to promote the integration of wind and solar alternatives in national and regional energy planning and sector restructuring as well as related policymaking. The project will enable informed decision-making and enhance the ability of participating governments to attract increased investor interest in renewable energy [25].

   Under the SWERA Project, high-resolution (approx. 0.05° to 0.15°, 1–3 hourly) site/time specific solar resource datasets will be derived from geostationary satellite-INSAT and METEOSAT5. It is expected that since INSAT has higher spatial resolution and METEOSAT has higher time resolution the combination will give the best product. Maps and GIS datasets of monthly and yearly sums of global radiation and of direct radiation covering the land areas of Bangladesh will be made available with an expected accuracy of better than 10% with respect to the annual sum of solar radiation. The maps will be based on 3 years of time series data with a time resolution of 1 h. Bangladesh will have

   - Access to enhanced solar resource maps and expanded databases including national validation results and expanded time series information.
   - The capacity to use the data in an effective manner to facilitate solar technology investment.
   - Understanding of how the resource data are developed.
   - Improved ability to undertake measurement programs for further validation data.
   - Site-specific pre-feasibility studies.

4. *REREDP:* The blended IDA/GEF Bangladesh REREDP supports the Government's development strategy to increase rural electricity access, and thereby promote social development and economic growth. This objective is sought to be achieved in the following four ways:
   - Assisting the REB to expand and intensify rural grids, improve the operational and financial performance of the rural co-operatives (known as PBSs), and reduce power outages in the rural grid systems.
   - Facilitating development of decentralized, mini-grids, based on natural gas, diesel, wind and hydro sources where feasible.
   - Promoting use of SHSs in rural areas inappropriate for grid expansion.
   - Increasing productive use of electricity and enhancing poverty impacts.

The project defines the institutional models, the stakeholders and implementing agencies, and financing and implementation details developed to place the renewables component within the context of a larger rural electrification strategy for Bangladesh. The blend IDA/GEF project will support this strategy, and a part of the IDA credit will be employed to promote large-scale application of renewables with investment and technical assistance resources [16].

1. *Establishment of a SHS-based pre-electrification program for PBSs:* The project will enable REB and five PBSs to develop a 'fee-for-service' SHSs market and install 14,000 SHS in rural households on this basis. IDA and Government will provide credit resources, with GEF grants to finance the SHSs program. Besides investment funding, TA resources are to be provided to strengthen institutional capacity, develop a sustained 'fee-for-service' PV market, provide implementation support and training, establish arrangements to test and certify equipment, monitor project progress, establish and operate a socio-economic cell in REB to design, implement and evaluate programs to use electricity to increase rural incomes and social well being, and establish sound performance monitoring and evaluation methods.
2. *Establishment of a SHS credit line and TA to support private sector, NGOs and MFIs:* The project will specifically support capacity building of private sector, PBSs, NGOs and MFIs to enter into and implement solar development programs. Capacity building would include generating awareness about solar-based opportunities, disseminating information widely and effectively, developing skills among 'institutions' and 'people' to implement and manage the program and training for solar technicians, community mobilizers and microfinance practitioners. The project envisages GEF financed TA, matched by IDA and Government, for market development and solar promotion. To overcome financing barriers, a renewable energy credit line from IDA resources and a GEF co-financing grant is proposed to be set-up and operated by the Infrastructure Development Company Limited (IDCOL) on commercial terms to finance 64,000 SHSs over a period January 2003–June 2008. IDCOL will on-lend to MFIs (or NGOs as the case may be) and solar businesses to facilitate the purchase of SHSs by consumers. Up to May 2005, 10 participating organizations (BRAC, COAST Trust, CMES, GS, IDF, Srizony Bangladesh, Shubashati, TMSS, UBOMUS, Singer Bangladesh Ltd.) has installed 42,699 SHSs allover the country.
3. *Promotion of renewable energy in selected rural areas of Bangladesh:* The main objective of the project is to test, promote and disseminate renewable energy in selected remote

areas of Bangladesh. The project period is 3 years and estimated cost is DM 4 million which will be funded by GTZ of Germany. GTZ has selected Bangladesh Rural Electrification Board as the implementing agency of the project. To achieve the project objective, the following five project outputs have been proposed by GTZ:

- Support of establishing an institutional framework for coordination of renewable energy activities at national level and facilitating development of suitable strategies.
- Adaptation and promotion of appropriate technologies for productive use of renewables in small-scale enterprises.
- Private-sector-based marketing, production, maintenance and recycling systems for renewables.
- Sustainable access to renewable energy services for selected self-help groups and social service providers at community level (e.g. schools, rural health clinics, cyclone shelters).
- Strengthening of technical and management capacities of major implementing agencies.

2.3. Hydropower

Hydropower generation is an eco-friendly clean power generation method. It is an established source of electricity and currently accounts for about 20% of electricity generation worldwide. In China, small hydropower (<1 MW) has been growing at rates in the range 7–13% per year over the past 20 years. In 1993, there were over 60,000 installations with a total capacity of 17,000 MW [22]. In India, mini/micro-hydropower capacity installed by the end of December 1995 is estimated to be 138 MW [21]. The total number of turbines installed in micro-hydropower plants in Nepal has been reported to be 933 with a total installed capacity of 8.7 MW [11].

The scope of hydropower generation is very limited in Bangladesh because of its plain lands, except in some hilly region in the northeast and southeast parts of the country. Bangladesh is a reverie country with three main rivers: Ganges, Brahmaputra and Meghna. 1.35 trillion m^3 of water flows through the country in an average water year. Numerous rivers flow across the country, which are mostly tributaries of these main rivers. Out of these, 57 rivers are Tran boundary, which originate from India and Myanmar. Apart from the south-eastern region, other parts of the country are mostly flat in nature. Major rivers of the country have high flow rate for about 5–6 months during monsoon season, which is substantially reduced during winter. More than 90% of Bangladesh's rivers originate outside the country, due to which proper planning of water resources is difficult without neighboring countries cooperation.

At present only 230 MW of hydropower is utilized in Karnafuli hydro station through 5 units of Kaplan turbine ($3\times50\,\text{MW}+2\times40\,\text{MW}=230\,\text{MW}$), which the only hydro-electric power plant operated by BPDB. BPDB is considering extension of Karnafuli hydro station to add another 100 MW capacity ($2\times50\,\text{MW}=100\,\text{MW}$). The additional energy will be generated during the rainy season when most of the year water is spilled. Apart from Kaptai, two other prospective sites for hydropower generation at Sangu and Matamuhuri River are identified by BPDB.

1. *Sangu project:* This would be a new project with an annual energy of about 300 GWh per year. For an installed capacity of 140 MW, the annual plant factor is 23%, and it is

estimated that the plant would operate in peaking mode. However, this project needs a detailed environmental, social and economic study in the present context.

2. *Matamuhuri project:* The Matamuhuri development would be a new project of capacity 75 MW and an approximate average annual energy 200 GWh per year.

2.3.1. Small hydro potential sites

Several attempts have been made in the past to find out the potential of s mall-hydropower generation, which is believed to be more environment or ecology friendly in comparison to large hydro with dams. Sites selected by some of the previous studies at different parts of the country are described in the following headings.

2.3.1.1. Sites selected by BPDB/Bangladesh Water Development Board (BWDB) joint study. To explore the possibility of hydropower from small hilly rivers/streams in the country, a working committee was constituted on February 1981 with officers from BWDB and BPDB. The committee explored 19 prospective sites for possible installation of small hydropower plants. The findings of the committee is summarized in Table 15 [16]. Later in the month of April 1984 a group of Chinese experts visited Bangladesh and identified 12 prospective sites in the hilly areas of Bangladesh. Out of those 12 sites, Mahamaya Chara, near Mirersharai, close to Dhaka–Chittagong highway was identified as the best site for development of small hydro. Accordingly BWDB is considering to develop a multipurpose project at Mahamaya Chara. It has been found out from the feasibility study that generation of electricity is possible throughout the year except in the month of April and May and a small hydropower plant shall be installed at the down stream foot of the proposed dam for the generation of electricity.

2.3.1.2. Sites selected by Flood Action Plan (FAP). In 1992, under the FAP, Northeast Regional Water Management Project (FAP-6) conducted a preliminary assessment of selected rivers in the Northeast Region. The finding for the most promising rivers and sites shows that they are suitable for development of run-off-river low head schemes. However, to obtain the required head for generating power a weir or barrage need to be constructed across the river channel. The identified site, along with the flow data, are listed in Table 15 [16]. Based on mean monthly discharges and an assumed 5 m head the hydro potential of the 10 major and medium perennial rivers of the Northeast Region is estimated as 161 MW, with an annual energy production of about 1410 GWh. These are perennial rivers with sufficient flow for power generation throughout the year.

There are also rivers which carry high discharges during the monsoon season and very small during the dry season. They have relatively high longitudinal slope across alluvial fans close to the Indian border. Most of the rivers have little flow in the winter months and sometimes they dry out completely. The suitable scheme would include diversion structure across the river channel, diversion channel along the bridge and the powerhouse at a suitable location that offers sufficient head. Nine rivers were identified in the study. The mean monthly power distribution from these rivers is given in Table 16. The potential annual power output of these rivers is estimated at 35 MW and the annual energy production at 307 GWh.

2.3.1.3. Sites in Teesta barrage project. Teesta barrage located in the North-Western part of the country. It is the largest irrigation project of the country. There are at least 19

Table 15
Summary of findings of BPDB/BWDB joint study and Flood Action Plan

Findings of BPDB/BWDB study		Findings of Flood Action Plan			
Name of River/Chara/ Stream	Potential energy (kW)	Name of river and site	Average year		
			Min	Mean	Max
Chittagong		*Meghalaya Group*			
Fiaz lake	4	Kangsha at Jariajanjail	16.7	274.3	738.5
Chota Kumira	15	Sari-gowain at Sarighat	6.4	128.2	381.9
Hinguli Chara	12	*Barak Group*			
Sealock	81	Surma at Kanairghat	6.4	524.4	1429.3
Lungi Chara	10	Surma at Sylhet	7.8	545.0	1470.1
Budia Chara	10	Kushiyara at Sheola	80.8	660.0	1610.0
Sylhet		Sonai-Bardal at Jaldhup	7.2	138.8	331.6
Nikhari Chara	26	*Tripura Group*			
Madhb Chara1	78	Manu at Manu River Barage	10.4	83.7	182.2
Ranga pani Gung	616	*Brahmaputra Group*			
Jamalpur		Old Brahmaputra at Mymensingh	19.4	704.9	2055.5
Bhugai-Kongsa	65.5	Lakhya at Demra	38.8	692.3	1750.9
Marisi	32.5	Old Brahmaputra at Bhairab Bazar	4.3	123.3	452.5
Dinajpur					
Dahuk	24				
Chawai	32				
Talam	24				
Pathraj	32				
Tangon	48				
Punarbhaba	11				
Rangpur					
Chikli	32				
Fulkumar	48				

potential sites of hydropower generation in the Teesta barrage project having 10 sites with more than 2 m head. The construction of these regulating structures have been completed and most of them are in operation. These sites can be investigated for development of small hydro projects. The prospective sites at Teesta barrage is shown in Table 17.

2.3.1.4. Sites in Chittagong hill tracks. There are lot of canals, tributaries of main river Karnafuli, Shangu, Matamuhuri as well as tiny waterfalls. The opportunities that exist in the CHT areas include the potential for the utilization of hydropower along with indigenous technical knowledge systems to operate local institutions. This study being carried out to harness of micro-hydro resources and find the potentials of setting up decentralized micro-hydropower unit with local implementation and management, thereby making remote tribal rural development possible through self-reliance and the use of local natural resources.

Example could be given form Mr. Aung Thui Khoin innovation of indigenous micro hydropower unit that draws attention of LGED and UNDP by wider coverage's press and electronic media. The unit constructed with wooden turbine and making an earthen dam

Table 16
Hydropower potential in Meghalaya rivers of Northeast region

River	Site	Catchments area	Estimated annual output	
		(km^2)	(MW)	(GWh)
Someswari	Dugapur	2134	5	43
Jadukata	Saktiakhola	2513	13	115
Jhalukhali	Dalura	448	5	45
Sarigoyain	Lalakhal TG	802	3	30
Lubha	Mugulgul	724	3	27
Dhalai	Khalasadaq	342	2	15
Umium	Chalelhnapur	518	2	20
Bhugai	Hatipagar	453	1	6
Darang	Ghosegaon	381	1	6
Total			35	307

Ref. [16].

Table 17
Potential sites in the Teesta barrage for small hydro power generation

Regulating structure (number)	Discharge (m^3/s)	Water level		Head (m)
		Upstream (m)	Downstream (m)	
Teesta Canal				
R3T	154.6	47.9	45.8	2.1
Rangpur Canal				
R2R	73.1	43.1	40.9	2.2
R4R	53.5	38.9	36.8	2.1
R5R	45.2	36.2	34.1	2.1
Bogra Canal				
S1B (L)	1.4	43.3	40.5	2.7
R1S2B	0.7	41.9	39.3	2.6
R1S3B	4.0	41.6	38.6	3.0
R1S4B	1.0	41.5	38.3	3.3
R1S5B	2.1	41.5	37.5	4.1
R3B	73.6	41.3	38.7	2.6

Ref. [16].

on the flowing Hara Khal at remote hilly region of Monjaipara, Bandarban. As observation, about 10 kW electricity is being generated by this indigenous micro hydropower unit that illuminated 40 households of that village. Focusing on that innovation, it is encouraging that such water micro-hydro unit may be undertaken to set up on potential sites in the off grid CHT region to bring up sustainability in socio-economic upliftment of the local backward tribal community. On primary discussion, LGED and UNDP come to the points that:

- The most temporary nature Mojaipara micro-hydro unit should be improved in order to make it sustainable.

- Such power unit should be replicated in the whole off-grid CHT region that are criss-crossed by numerous canals, tributaries that holds potential sites.
- On Bamer-chara, such micro-hydropower unit may be set up for improvement of tourism, irrigation, and provide power to local inhabitants.

On the above-mentioned ground, an agreement has been signed between LGED and innovator Mr. Aung Thui Khoin for a month long study. From the study report eight different prospective sites have been found for micro hydropower development, which are described in Table 18.

2.3.2. Organizations and their activities for the development of small hydropower

Summary of the several attempts have been taken up by some of the government organizations and international organizations for the development of the small hydropower are presented in the following sections.

2.3.2.1. Projects by government organizations.

1. *Micro-hydropower potential site at Bamer-chara irrigation project by LGED:* LGED has been exploring the potential of mini and micro hydropower as eco-friendly sources of energy in the hilly region to meet the different energy needs of the remote inaccessible, underdeveloped and sparsely populated mountain areas. Several studies carried out in Bangladesh recommended that mini and micro-hydro alone might not be a feasible option in this country. However its integration with irrigation and flood control projects can be made economically viable. In this regard, LGED has implemented Bamer-chara irrigation project in Banskhali Thana under Chittagong district with an intention to provide irrigation facilities to 355 ha land. A large reservoir has been built in this project for dry season irrigation. Water enters the project area through a gated spill way and flow is controlled at the downstream by a conventional regulator. Currently LGED is examining the flow rate in the spillway and exploring the scope for installing a micro-hydropower plant at the site [16].

Table 18
Prospective sites for micro hydropower development in CHT

Name of canal with location	Sectional area (m^2)	Lowest flood level (m)	Highest flood level (m)	Power potential (kW)
Nunchari Tholi Khal in Khagrachari	11	0.06 (May)	3	5
Sealock Khal in Bandarban	25	0.15 (April)	4	30
Taracha Khal in Bandarban	35	0.1 (April)	6	20
Rowangchari Khal in Bandarban	30	0.1 (April)	5	10
Hnara Khal in Rangamati	20	0.15 (May)	4.20	10
Hnara Khal in Rangamati	25	0.12 (May)	4	30
Monjaipara micro-hydropower unit	15	0.50	1	10
Bamer Chara irrigation project	—	—	—	10

2. *Micro hydropower plant at Barkal by BPDB:* Barkal is one of the remote and unelectrified Upazila (sub-district) in the Chittagong Hill Tracts region. The area is covered with hills ranging 300–500 m in height. Due to the geological structure, the area is remote in terms of building the infrastructure. Therefore, the extension of grid electricity will be very difficult and expensive. Engineers of BPDB have conducted reconnaissance survey in the Upazila and identified availability of water sources for micro hydropower plant. Based on the electrical load demand of the adjacent area, 20 kW micro hydropower plant have been designed with the help of RETScreen, developed by CANMET Energy Diversification Research Laboratory of Canada (CEDRL).The project will be funded by the Ministry of Chittagong Hill Tracts Affairs.
3. *Feasibility study on R&D of renewable energy by IFRD:* ''Feasibility study on R&D of Renewable Energy (Solar, Wind, Micro-Mini Hydro)'' of IFRD (described in Section 2.1.3) has collected data through the related instruments regarding the micro-mini hydro study at two selected places of Shailopropat in Banderban and Madhobkundu in Moulibhibazar. The collected data and information are analyzed on various aspects at RET laboratory of IFRD. On the basis of analysis of collected data up to June 2001, it is expected that 5–10 kW and 10–20 kW capacity micro-hydropower plant can be installed for electricity generation at Sailipropat and Madhobkundu sites, respectively. Summary of different measurements and calculations for small hydropower generation are shown in Table 19.

2.3.2.2. Bilateral and multilateral development partner-assisted projects

1. SRE *project of LGED:* The SRE project of LGED (described in Section 2.1.3) has a plan to consider the development framework for micro-hydropower program at potential sites in Bangladesh.
2. *REREDP:* The REREDP (described in Section 2.2.3) project has also taken a program for development framework for hydropower. The project will provide support for assessment for run-of the-river mini-hydro in the hilly regions. If assessments indicate positive potential, IDA would support development and implementation of pilots to confirm commercial feasibility. Support will in that case be extended to formulate a policy framework for commercial development of these resources, including development of Small Power Purchase Agreement (SPPA) and incentives.

Table 19
Summary on micro hydropower generation in hilly districts

Name of water Falls	Average discharge (l/s)	Approximate duration of flow (months)	Probable fall for hydro power generation (m)	Elect-Rical power (kW)	Annual energy production (kWh)
Sailopropat	100	12	6	5	43,800
Madhobkundu	150	12	10	15	131,400

2.4. Tidal energy resource potential

Tidal power utilizes the twice-daily variation in sea level caused primarily by the gravitational effect of the Moon and, to a lesser extent the Sun on the world's oceans. The Earth's rotation is also a factor in the production of tides. The normal tidal head rise and fall in the coastal region of Bangladesh is between 2 and 8 m as shown in Table 20 [16]. This tidal range can easily be converted to pollution free clean renewable energy by using the simple low-cost technology of a "tidal wheel" in the sluice gates. The real benefits of this technology however are that it can be applied in a way that simultaneously enables the development of local infrastructure and various resource producing activities such as agriculture and aquaculture along with improved living conditions for the local people [26]. A demonstration tidal power project is being planned in Sandwip, one of the coastal island of Bangladesh, by ISTP of Murdoch University, Australia. ISTP has developed a feasibility plan for rebuilding a recently damaged sluice gate with a trial paddle wheel [27]. If become successful, the tidal project of Sandwip can be replicated in the other coastal areas and which will usher new light in the region.

2.5. Wind energy

Production of wind-generated electricity has risen from practically zero in the early 1980s to more than 10 TWh per year in 1996. The total installed wind power plants in the world in 2002 were about 30,000 MW. Germany has installed 12,000 MW, which was the highest in the world. In Asia, India has the highest installed capacity of 1175 MW and it ranked fifth in the wind power generation in the world.

Table 20
Tidal levels in coastal Bangladesh

Station	LAT	MLWS	MLWN	ML	MHWN	MHWS	HAT	TD (AT)
Hiron Points	−0.256	0.225	0.905	1.700	2.495	3.175	3.656	3.912
Sundarikota	−0.553	0.036	0.636	1.829	3.022	3.694	4.211	4.764
Mongla	−0.261	0.325	1.194	2.310	3.427	4.296	4.882	5.143
Khal no. 10	−0.444	0.261	1.231	2.664	4.097	5.067	5.772	6.216
Sadarghat	−0.423	0.239	1.100	2.481	3.861	4.722	5.385	5.808
Cox's Bazar	−0.339	0.205	1.023	1.995	2.967	3.785	4.329	4.668
S. Island	−0.348	0.191	1.045	1.874	2.703	3.557	4.096	4.444
Sandwip	−0.583	0.238	1.634	3.243	4.851	6.248	7.070	7.653
Char Changa	−0.375	0.256	1.060	2.037	3.014	3.818	4.449	4.824
Khepupara	−0.323	0.195	1.025	2.060	3.096	3.925	4.445	4.768
C.Ramdaspur	−0.261	0.189	0.763	2.036	3.309	3.883	4.333	4.594
Barisal	+0.134	0.434	0.692	1.539	2.386	2.644	2.944	2.810
Chandpur	+0.019	0.256	0.493	2.172	3.852	4.088	4.326	4.307
Nalmuri	+0.078	0.370	0.722	2.195	3.669	4.021	4.313	4.235
Narayanganj	+0.458	0.585	0.697	2.770	4.844	4.956	5.083	4.625
Galachipa	−0.159	0.283	0.937	1.764	2.592	3.245	3.689	3.848
Patuakhali	−0.143	0.242	0.740	1.575	2.409	2.907	3.293	3.436

Explanation: MLWS = mean low water spring, MHWS = mean high water spring, MHWN = mean high water neap, MLWN = mean low water neap, ML = mean level, AT = astronomical tide, LAT = lowest astronomical tide, HAT = highest astronomical tide, TD = difference between lowest and highest tidal height in meter.

The Bangladesh Meteorological Department has wind speed measuring stations in towns and cities. Data from earlier measurements and analysis of upper air data by CWET India show that wind energy resource of Bangladesh is not good enough (>7 m/s) for grid connected wind parks [25]. Total wind power generation in Bangladesh is reported as 50 kW [28]. It is 0.001% of total installed power plant of Bangladesh (4995 MW). Wind data from Bangladesh Meteorological Department and different wind resource assessment projects are briefly described in the subsequent sections.

2.5.1. Wind data from Bangladesh meteorological department

Most of the previous wind speed data in Bangladesh is available from the Bangladesh Meteorological Department. Average values calculated from such wind data during 1961–1993 are presented in Table 21. Bangladesh Center for Advanced Studies (BCAS) obtained and reviewed Bangladesh Meteorological Department's wind data with a view to establishing the prospects for wind energy. The following information about the wind climate in Bangladesh had been found:

- Wind speeds at most Met Office stations appear to be low, with typical annual mean wind speeds of 1–2 m/s, at heights between 5 and 10 m above ground level.
- Wind speeds appear to be higher in the eastern part of the country than the western part.
- Wind speeds in the coastal areas appear to be higher than inland.
- Wind speed exhibits a strong seasonal cycle, lowest in the winter and higher in the summer.
- Wind speed exhibits a diurnal cycle, generally peaking at noon and weakest at night.

2.5.2. The Wind Energy Study (WEST) project

The WEST project of BCAS was an attempt to collect wind-speed data through technically sound monitoring system, since no such study had previously been done in Bangladesh. The project was approved by Aid Management Office, Dhaka (AMOD) in September, 1995. BCAS has been provided with necessary technical assistance and cooperation by Energy Technical Support Unit (ETSU), Harwell, UK in the implementation of the project. LGED helped in installation of the wind monitoring masts, collection and dispatch of data cards from the monitoring sites to BCAS

Table 21
Annual average wind speed of different sites in Bangladesh during 1961–1993

Site	Reference height (m)	Wind speed (m/s)	Site	Reference height (m)	Wind speed (m/s)
Teknaf	5	2.16	Hatia Island	6	2.08
Cox's Bazar	10	2.42	Bhola Island	7	2.44
Potenga Airport	5	2.45	Khepupara Island	10	2.36
Kutubdia Island	6	2.09	Comillah Airport	6	2.21
Sandip Island	5	2.16			

Table 22
Monthly average wind speeds at 25 m height with percentage frequency above 4 m/s

Month		Patanga	Cox's bazaar	Teknaf	Noakhali	Char Fassion	Kuakata	Kutu- bdia
Jun. 1996	S	8.75	—	—	—	—	—	—
	F							
Jul. 1996	S	5.87	5.42	5.77	—	—	—	—
	F	76.78	65.09	70.81	—		—	—
Aug. 1996	S	5.32	5.33	4.90	4.70	5.20	5.70	—
	F	65.77	63.66	57.97	60.74	59.46	81.14	—
Sep. 1996	S	3.36	3.69	3.46	2.94	3.34	3.77	3.58
	F	32.82	34.14	34.49	25.93	25.3	45.14	36.89
Oct. 1996	S	3.20	3.74	3.30	2.83	3.70	2.81	3.98
	F	25.07	36.18	31	16.53	25.43	18.01	43.64
Nov. 1996	S	2.61	2.93	2.29	1.91	Lost	1.98	3.23
	F	6.62	24.54	18.84	5.35	Lost	5.53	35.49
Dec. 1996	S	2.97	1.78	1.44	1.35	3.09	3.35	3.38
	F	12.86	19.76	16.49	5.22	28.96	21.26	40.3
Jan. 1997	S	3.25	2.33	1.99	1.31	2.80	3.18	3.67
	F	22.78	25.96	24.53	6.85	23.63	27.15	41.73
Feb. 1997	S	2.66	1.99	1.90	1.90	2.69	3.37	3.29
	F	17.41	20.81	21.9	14.58	21.75	29.18	35
Mar. 1997	S	3.13	2.42	2.26	2.38	3.54	4.84	3.53
	F	32.86	28.52	26.39	24.13	35.78	55.98	40.66
Apr. 1997	S	2.88	1.84	1.65	2.25	3.29	4.93	3.11
	F	27.94	18.7	15.23	24.05	37.22	56.02	31.37
May 1997	S	4.96	3.97	3.09	3.99	4.81	6.28	4.89
	F	58.42	45.56	33.4	48.48	55.76	78.83	61.07
Jun. 1997	S	5.83	4.64	3.26	5.00	5.76	7.31	5.90
	F	73.84	59.56	40.49	64.7	70.53	87.94	79.14
Jul. 1997	S	5.67	4.80	4.33	4.92	5.22	7.34	6.17
	F	70.45	60.37	48.96	63.75	49.55	90.46	79.12
Aug. 1997	S	5.13	4.31	4.03	3.85	5.17	—	5.34
	F	68.67	53.29	50.99	43.73	55.49	—	66.51
Sep. 1997	S	—	2.96	1.83	2.77	3.08	—	3.97
	F		30.67	16.11	27.62	32.2	—	45.05
Annual average	S	3.95	3.34	2.94	2.96	4.07	4.52	4.21
	F	42.31	39.12	36.26	33.20	45.39	66.29	48.92

Explanation: S = wind speed and F = percentage frequency above 4 m/s.

Headquarters at Dhaka on regular basis. These studies mostly concentrated wind observations in the seven coastal regions: Patenga, Cox's Bazar, Kutubdia, Teknaf, Noakhali, Kuakata and Char Fassion.

The final report of WEST indicates that the average monthly wind-speed is relatively high during the months of April through August and low during September–March. The average annual wind speed values at 25 m height for the seven stations vary from 2.96 to 4.54 m/s. The highest average annual value (4.54 m/s) was observed in Kuakata and the lowest value (2.96 m/s) was observed in Teknaf and Noakhali. Table 22 [16] shows the monthly average wind speeds at 25 m height with percentage frequency above 4 m/s from seven WEST stations.

2.5.3. TERNA Project

TERNA Project was initiated by Bangladesh Atomic Energy Commission (BAEC) and the REB. Site selection took place in March 1996. In cooperation with GTZ of Germany, measurement systems were installed and the collected data were analyzed as part of a training course for REB-engineers. TERNA Project has collected wind data in four selected sites with the help of REB. The sites were located at—Patenga, Anwara, Teknaf and Feni. The project concluded that "the mean annual wind velocities are to low". The monthly average wind speed at Patenga is shown in Table 23.

2.5.4. Technologies practice for wind energy

Wind energy utilization in Bangladesh is in the early stage of application. Several locations have already been assessed to evaluate the wind energy potential of the coastal region of the country. Variation of wind resource has been observed among the different locations in the region. In addition, seasonal variation of wind resource prevails in the country, with a strong potential during the months of April–September, and a very weak potential during rest of the year. However, scope of utilization of wind energy resources can become effective in certain cases of exclusive applications including wind water pumping and power generation through wind–diesel hybrid systems.

2.5.4.1. Water pumping windmills. LGED has designed and manufactured low cost wind pumps with a rated capacity of 20,000 l of water per day at 4.0 m/s wind speed. Six such prototypes are already installed at different parts of the country. It has installed four water-pumping windmills in year of 1999. Two water-pumping windmills in year of 1999 and one wind–solar hybrid system in the year of 2000 have been installed under SRE project. BRAC has installed 10 wind turbines for water pumping. It has also installed 6 PV–wind hybrid systems. Bangladesh Army (BA) has also installed 1 windmill in Chittagong Hill Tracts. The summary of wind energy installation by different organizations is given in Table 24.

2.5.5. Organizations and their activities for the development of wind energy

Summary of the several attempts have been taken up by some of the government organizations, NGOs and international organizations for overall development of the wind energy have presented in the subsequent sections.

Table 23
Monthly average wind speed at Patenga

Month	1995	1996	Month	1995	1996
January	—	—	July	8	8.4
February	—	—	August	7.4	3.5
March	6.7	—	September	6.8	3.9
April	7.2	—	October	6.2	3.2
May	7.7	8	November	4.4	2.6
June	8.1	6.9	December	4.2	2.2

Ref. [16].

Table 24
Total wind energy installation by different organizations

Type of installation	Capacity (Wp)	Sites of installation	Installation done by
SSHTT	373	Begum Hamida Siddique School, Boria, Kushtia	LGED
SSHTT	373	Cox's Bazar Sea Beach, Cox's Bazar	SRE
SSHTT	373	Executive Engineer's Office, Tangail	LGED
SSHTT	373	Gulbahar Ashik Ali College, Kachua, Chandpur	LGED
SSHTT	373	Bonal para Junior Girl's School, Nalitabari, Sherpur	LGED
SSHTT	373	Losmanpur pir Shaheb-Bari, Sherpur	SRE
Hybrid	400	Kuakata Sea Beach, Patuakhali	SRE
3 Hybrid	4500	Grameen offices in the coastal region	GS
Hybrid	7500	Cyclone shelter in the coastal region	Gs
Stand-alone	900	Coastal region	BRAC
Hybrid	4320	Coastal region	BRAC
Stand-alone	400	Chittagong Hill Tracts	BA
Stand-alone	1100	Teknaf	IFRD
Stand-alone	600	Meghnaghat	IFRD

Ref. [16,29]; Explanation: SSHTT = slow speed high torque turbine.

2.5.5.1. *Projects by government organizations.*

1. *Wind Resource Assessment Program (WRAP) of BPDB:* In order to generate electricity from wind energy, a 50 m high wind tower was installed at Muhuri Dam area in Feni to assess the speed of wind. One year's wind speed data has been collected from this tower. The average measured speed has been found satisfactory. On the basis of this average suitable speed, tender was invited for installation of 8×225 kW windmill. A contract was signed with M/S Nabula Techno Solution for installation of 4×225 kW windmill from revenue budget of BPDB. A total of 22% work has already been completed during FY 2003–2004. Another 3 units of wind towers have already been installed at Magnama ghat, Patenga (Parkey Saikat) and Kuakata. Primary readings collected from these sites are found to be satisfactory [30].
2. *Feasibility study on R&D of renewable energy by IFRD:* Recently a project on "Feasibility Study on R&D of Renewable Energy (Solar, Wind, Micro-Mini Hydro)" has been undertaken by the IFRD of BCSIR. Under this program, wind speed data have been collected at three sites: Saint Martin, Teknaf and Meghnaghat. The maximum velocity obtained at Saint Martins Island is 30 m/s and yearly average wind speed is 4.9 m/s. The maximum velocity obtained at Teknaf is 16 m/s and yearly average wind speed is 3.8 m/s. Available wind speeds in the Saint Martin's Island are presented in the Table 25. IFRD has already imported 3 NEPC 2500, 1100 and 600 Watt wind turbines. The 1100 W turbine is installed at the sea beach of Tecknaf and 600 W turbine is installed at Meghnaghat. It has been observed that maximum 600 and 200 W power has been collected from Teknaf and Meghnaghat, respectively.

Table 25
Monthly average wind speeds in the Saint Martin's Island

Month	V_{av} (m/s)	V_{max} (m/s)	Month	V_{av} (m/s)	V_{max} (m/s)
January	5.08	23.32	July	5.33	24.20
February	4.71	19.78	August	5.96	20.40
March	4.29	18.94	September	4.79	17.70
April	3.58	20.03	October	4.17	15.90
May	5.75	26.30	November	3.79	14.50
June	5.96	29.80	December	4.08	15.20

Ref. [16].

2.5.5.2. Bilateral and multilateral development partner-assisted projects.

1. *Wind Energy Resource Mapping (WERM) in Bangladesh:* As a consequence, wind energy development project could not be formulated in Bangladesh with only 1-year observation. In this backdrop, SRE project, in collaboration with Bangladesh University of Engineering and Technology (BUET) and Chittagong University of Engineering & Technology (CUET), has taken up a study on titled "WERM" in the year 2000. The study has been designed in a more comprehensive way aiming at systematic observation on wind regime in initially 20 different suitable locations including Chittagong Hill Tracts region over a longer period of time. The monitoring stations have been listed with their location in Table 26.

3. Discussions

3.1. Benefits of RETs: Bangladesh perspective

Biomass and kerosene are the major sources of energy in rural areas. Promoting renewable energy sources for rural energy requirements in conjunction with alleviation of rural poverty, diversification of energy resources and reduction of oil imports are needed to shift the economical growth towards greater sustainability, as well as environmental and social stability. Information on the socio-economic aspects are limited. The available data are scattered and least quantified. So, it is difficult to assess full impact of renewable energy in the country both socio-economically and environmentally. In the subsequent sections, different socio-economic benefits are described briefly.

1. *Reduction in electricity transmission and distribution cost:* There are more than 87,319 villages in Bangladesh, and most of them are unconnected to the national grid. It is estimated that only 22% of our rural householders are hooked on the grid. The electrification by grid extension or secondary power station can only reach a small minority of the population in rural areas. In view of the dispersion of localities and the low demand, the cost of production, transmission and especially distribution of electricity would be prohibitively expensive. Decentralized RETs/PV systems like stand-alone family lighting kit could effectively become a viable option in these areas. One of the essential features of the family lighting kit is its modularity, it can be tailored to the

Table 26
Location of 20 wind monitoring stations

Name and location of stations	Latitude	Longitude	Height (m)
Engineering Staff College, Munshigonj	23°32.73′N	90°39.41′E	40
CUET Campus, Chittagong	22°30.27′N	91°55.92′E	20
Muradpur, Sitakunda Chittagong	22°35.68′N	91°42.52′E	30
Hridoy Member para, Alutila, Khagrachari	23°05.45′N	91°57.67′E	20
Baulkhali, Ting Restaurant, Rangamati	22°36.22′N	92°11.28′E	20
Prantik Lake, Bandarban	22°12.43′N	92°12.31′E	30
Teknaf Sadar, Cox's Bazar	20°49.19′N	92°15.38′E	20
Dublar Char, Bagerhat	21°52.31′N	91°55.18′E	01
Akbar shah Light House, Kutubdia town, Cox's Bazar	21°54.71′N	91°52.43′E	20
South Moghdhara, Sandwip Town, Chittagong	22°27.57′N	91°29.71′E	20
Betua-ghat, Charfession, Barisal	22°12.43′N	90°42.18′E	20
Kalapara, Kuakata , Patuakhali,	21°54.76′N	90°08.24′E	30
Chila Bazar, Mongla, Bagerhat	22°29.73′N	89°40.99′E	20
Rupur Diar , Pakshy Bridge, Pabna	24°08.65′N	89°06.53′E	30
Char Anupnagar, Chapainawabganj	24°41.26′N	88°24.47′E	20
Bharatto Dubal-hati, Naogaon Sadar, Naogaon	24°50.81′N	89°04.75′E	20
Begum Khaleda Zia Girls High School, Tentulia, Pancharh	26°27.57′N	88°36.12′E	20
Tail gaon , Tuker Bazar, Sylhet Sadar, Sylhet	24°55.68′N	91°55.92′E	20
Balisera Tea Estate, Kaligath, Sreemangal, Moulvibazar	24°33.27′N	91°54.17′E	20
Kamalpur Noahati Barrage, Mithamoin Sadar, Kishoreganj	24°27.92′N	91°09.90′E	30

Ref. [16].

real needs of each consumer. Other advantages are:

- They do not require any grid lines to take the power to each house.
- With no distribution and transmission lines losses are eliminated and theft of electricity is avoided.

2. *Opportunity for saving foreign currency:* Throughout the country, different government administrative offices, NGO offices, health centers, schools, banks, police stations etc. are functioning. In the off-grid locations, these offices are either using traditional means (lantern, candles, kerosene wick lamps, etc.) or operating their own diesel gensets. These offices have separate budgets for electricity and they can be easily served with solar PV applications. Bangladesh imports diesel with hard-earned foreign currency. It is obvious, that by substituting the diesel gensets with RETs can diversify the energy mix and thereby save foreign currency. It is established fact that RETs can promote energy security and price stability by diversifying the energy supply. As RETs are modular, energy requirement can be met on-site very quickly and can be scaled up in the course of time with growing demand. Another problem associated with the conventional grid is line interruptions, which in the case of RETs are much less and can be avoided if the user is trained properly.
3. *Development opportunity for Chittagong Hill Tracts (CHT):* There are lot of canals, tributaries of main river Karnafuli, Shangu, Matamuhuri as well as tiny waterfalls having potentials for setting up mini/micro hydropower unit in CHT region. CHT is being almost isolated form governmental and non-governmental development initiatives for many years because of remoteness and terrain landscape, scattered settlement pattern, lack of infrastructural development and diversification of

economies. Confronting sustainable development issues in CHT and seeking local solutions, considering natural resources and ecosystem, development of affordable indigenous and sustainable technologies is viable options to promote livelihood at CHT. Since power is key indicator in all development strategies, harnessing micro-hydro resources and setting up decentralized small-scale water power or micro-hydro schemes are a particularly attractive option in terrain areas without hampering ecosystem. Extension of grid electricity is not economically feasible at the remote mountain areas like CHT because of scattered settlement and lack of infrastructural development.

4. *Improved facilities for social activities:* The installation of solar PV technology in some rural localities of Bangladesh has brought significant changes in the awareness of people and also improved their quality of life. The initial reaction of the villagers was one of apathy and disinterest. However, when the community system became functional, the situation changed radically, people came in groups to watch TV. A large number of people from the neighboring villages were also attracted. The initial apathy first gave rise to curiosity and then to total acceptance and a feeling of pride. With lighting available, living habits improve. Leisure and entertainment from TV programs which were a short time ago a privilege of urban life could be routinely viewed by rural families. Public life was almost inexistent before street lighting were operational. Villages were seen teeming with life after darkness till late hours under the solar light. In the community centers, adult education programs, meeting of villagers and social gatherings were regular features.
5. *Creation of better environment for rural education:* Most of the rural off-grid schools don't have electricity. RETs can be used by these rural schools for different amenities. Modern benefits will not only attract more students, but will also retain quality teachers and staffs currently unwilling to be posted in the unelectrified areas. In the evening, the school facilities can be utilized for other social services like adult education, health education or recreational activities. Kerosene lanterns and candles provided inadequate lighting, cause pollution and entail fire hazard. RETs/PV lighting is more stable and brighter. With this good quality light, school children get better vision for their homework, with less or no strain, productive activities can also be carried out during the evening hours by housewives. PV systems provide also better lighting and at lower cost than dry-cell batteries. The dry-cell batteries not only are often of poor quality, but they can take a significant fraction of low income of a poor family. They have a short lifetime and there is no disposal.
6. *Employment opportunity:* RETs are up to three times more employment-intensive than fossil fuel or nuclear power plants. This benefit can be easily seen from the global wind energy business. According to a survey by Danish wind energy manufacturers, 17 worker-years are created for every megawatt of wind turbine manufactured and five worker-years for every megawatt wind power installed. In the year 2000, the wind energy industry provided more than 85,000 jobs worldwide and could provide up to 1.8 million jobs by 2020. Electrification of microenterprises in the off-grid areas can increase income or create new job opportunities for the rural poor which has been observed from the experience of GS,which is a leading NGO involved in the RETs sector.
7. *Improved facilities for rural health center:* At present, a large amount of population is deprived of proper health care due to absence of electricity in remote far-flung areas. Provision of health care in rural areas is a major concern, therefore rural health centers are integral parts of the primary health care systems in Bangladesh. However, their

ability to deliver basic health services depends on the availability of electrical energy, particularly for vaccine storage, lighting and safe water. Family health, especially maternal and infant welfare, has been improved when health centers in rural areas were upgraded by providing them with solar PV energy. This has ensured, to some extent, the success of the immunization program.

Electrification helps family planning activities. An exhaustive analysis to find out the link between electrification and fertility in Bangladesh shows that the fertility rate among girls is 0.67 in electrified households and 1.17 in non-electrified households.

8. *Solution of drinking water in remote islands:* After the installation of RETs/PV water-pumping systems, water requirements for gardens, vegetables, cattle breeding and cash crops had yielded substantial gains to peasantry and had increased their income. Drinking water was also secured on long-term basis. This is a major social benefit, as impure drinking water is responsible for a large fraction of infant mortality. The fact a storage tank is included in the solar water pumping system means reducing the drudgery of fetching water for women. Beside the costal area, there are several islands lacking in potable water for drinking. Using solar water desalination technology to tackle the water shortage problem has had a real impact on the standard of living within these islands.
9. *Development of rural women life style as well as safe environment:* Provision of electricity has many effects that can benefit women. However, PV does not solve the urgent need of a satisfying energy source for cooking. Domestic cooking is a major consumer of lignocellulosic biomass. Women are solely involved in this activity. To collect tree biomass, women, sometimes assisted by children, spend several hours a day. Though, it is done free, releasing women from doing mundane work will empower them. Indeed, women will get more time for self-advantage: adult literacy, actualization about nutrition, family planning, skills training such as sewing, etc., thus better child care, gardening and hence increased revenue. This affects the nutrition and the health of the entire family.

Ecological and environmental impacts may be raised for the use of lignocellulosic biomass. The distribution of fragile forest resources has led to desertification and reduced agricultural productivity as a result of declining soil fertility, decreased groundwater recharge, loss of biodiversity and other micro-climate effects. Deforestation has a negative effect on both the environment and women's health, bringing in less income, necessitating more work and increasing the downward spiral of poverty. Education, especially of girls, suffers when fuel wood and water resources are scarce. Incomplete combustion of fuel wood from traditional stoves generates harmful air pollution such as carbon monoxide, suspended particulates, sulfur oxides, nitrogen oxides and hydrocarbons that have been linked to eyes and respiratory diseases. Environmental degradation thus affects not only their ability to look after their family's nutrition and health, but also their own health, well-being and income generation activities. Introduction of renewable energy is the quickest way to initiate a program of social upliftment for the majority of people in rural areas. With the use of improved stoves, biogas or solar cooker women find a great relief at home as pollution is minimized. On a global level, burning wood releases carbon dioxide and other greenhouse gases that threaten a global warming.

Biogas plants have not only the advantage of improved efficiency and multidimensional use, the GHG emissions will also be reduced and organic fertilizers will be available as a

by-product. Impact of biogas plant on health and environment are: reduce health hazards in kitchen and improve quality of women households works, reduce higher level of deforestation and net greenhouse gas emissions; improves air quality and reduce acid deposition; improve soil quality and reduce erosion; reduce land filling by adding value to residues; improve sanitation condition; improved habitat for wildlife and reduced use of fertilizers and insecticides compared with lands used for row crops, protection of riparian areas, and erosion protection for sensitive land areas. Reduction of Greenhouse Gases from biomass power takes place because the carbon dioxide released during combustion is absorbed by the plants as they grow.

3.2. Issues and barriers

It is evident that like many other countries in the South Asian Region Bangladesh has already initiated promotion of RETs systems. However the penetration levels and deployments differ from other countries, with India having extensive experience in almost all type of RETs and promotional models. In case of India, some the issues have been partially addressed, e.g. establishment of separate ministry for RE (MNES) and financing institution (IREDA) specifically for RETs. The barriers, which are affecting full realization of the RETs potential, could be broadly categorized into:

1. *Policy and regulatory:* The lack of clear, long-term and consistent policy is the major issue in Bangladesh. With lack of strong RETs policy, based on proper resource assessment and planning, various RETs initiatives seems adhoc and intermittent and thus fail to become part of overall mainstream energy planning at government level. There is recognition of importance of RETs but policy remains at 'guideline' level without budgetary and legislative backup for the policies.
   Though the reform process started quite early in India, Bangladesh is at initial stages or in some cases the process have not yet started. But from the experience of India it is clear that RETs have to be properly positioned in order to grow under the reformed scenario.
   Some of the conventional energy sources are provided with subsidies, direct as well as hidden, thus favoring the conventional sources. This is hampering the competitiveness of the RETs. Till now Bangladesh, not like India, there is no legislative support for RETs. There is a lack of sufficient financial incentive policies to encourage renewable energy development. Besides we have also lack of legal, regulatory and policy framework for market oriented renewable energy programs. Most of the renewable energy programs in Bangladesh are primarily technology-driven and focus on R&D, rather than emphasize promotion and encouragement of commercialization and private sector involvement.
2. *Financial:* The high initial cost of RETs is a barrier especially in the developing countries where income levels are low. The issue of providing subsidies, to address the issue of high initial cost, have been discussed at various levels, including its impact on the market. Suitable/sufficient subsidies are essential in order to make RETs affordable to the users. However in the absence of mechanisms for effectively targeting them, these act as barriers. The high costs of these technologies result in lower rates of returns, though on lifecycle basis these technologies are viable. Moreover, the high market interest rates limit use of RETs. Absence of innovative financing options (or lack of

appropriate financing mechanisms), like micro-credits are critical issues in this region (though there have been successful examples of RETs initiatives with innovative financing models like the "GS" promoting solar PV systems in the country).

3. *Institutional:* Renewable energy based provision of modern energy services is dealt with by various ministries, agencies and institutions, making good coordination between them a necessity to efficiently make use of limited human and financial resources in the country. There is provision lengthy and difficult process for permission. Dependency on the national budget for implementation of activities, which creates uncertainties in allocation of project financing as well as time delays associated with decision-making. Limited spatial distribution of suppliers limits access to RETs.
4. *Technical:* There is a lack of standards and quality control for renewable energy equipment. We have a great lacking of domestic manufacturing. Bulk procurement of RETs is limited due to the current small market for renewable energy based modern energy services. Hence the (technical) infrastructure to support renewable energy development does not exist. Local manufacturing and/or assembly of RET components are currently very limited, although the knowledge, skills, expertise and facilities are available in the country. Limited technical capacity to design, install, operate, manage and maintain renewable energy-based modern energy services, mainly as a result of lack of past activities in this new field.
5. *Information:* Lack of accurate resource, technical/economic information about RETs, equipment suppliers, and potential financiers is a barrier in Bangladesh. The absence of precise resource data limits the inclusion of RETs in the planning process and designing of specific promotional programs.

The R&D efforts to develop/adapt specific RETs products to meet the local market requirement are essential for successful RETs program. Lack of development of appropriate products based on assessment of local needs is limiting the use of renewable energy resources. The support for market creation and facilitation without taking into account the local development/need usually results in end of any initiative after cessation of the support program. There is even lack of pre-investment support for demonstration, technology transfer, performance testing etc. Availability and access to existing renewable energy resource information is limited. A central information point does not exist, instead information is scattered among various sectors; e.g. public sector, development assistance, R&D centers and academia. There is lack of public awareness on RETs other than that they exist. For example, knowledge that the life cycle costs of most RETs are often competitive or even lowest among cost options is mostly absent.

4. Concluding remarks

Dissemination of biomass and solar energy throughout the country should be first priority in solving our energy crisis. There is no way other than taking bio and solar energy for reducing environmental degradation. Scientists of the world are now seeking energy solution from the two resources, which are highly available in the country. By generating biomass and solar energy from our abundance sources we can solve a big portion of energy deficiency. The energy sector of the world is evolving remarkably. It is facing an accelerating compound crisis of the globally established fossil (oil) and atomic energy system; therefore, immediate different breakthroughs for bio and solar energy are necessity

to reach our electricity goal. We are going to run out of gas in the next 25 years. Frequently escalating oil prices indicate the depletion of fossil resources and the urgent need to replace the current mix of fossil transport fuels.

Market survey for wind, small-hydro, modern biomass or other types of RET applications are not yet been done properly. From the previous resource potentials it can be implied that micro hydropower plants can be installed in the north-eastern hilly regions and in the existing irrigational canal system with sufficient head. There are scopes of integrated tidal power plants in the coastal regions.

More than 90% of Bangladesh's rivers originates outside the country, due to which proper planning of water resource s is difficult without neighboring countries cooperation. Downstream water sharing with India is a highly contentious issue in Bangladesh.

The annual wind speed at a height of 25 m at some coastal locations is above 4 m/s and much higher in the pre-monsoon and monsoon periods. It appears that such sites are suitable for power generation, particularly using PV or diesel hybrid technique for winter months. Water pumping for agriculture in pre-monsoon months and for drinking water over the year should be feasible for some inland locations with lower wind speed. Small wind turbines can be installed in the coastal region and off-shore islands of the country.

The overall effect of community facilities such as school, health centers or water pumping can contribute significantly to welfare and rural development. And the tendency to emigrate from rural areas to urban cities has been stemmed, even a quantum leap in the quality of life has been raised. Above all, rural electrification is viewed as a mean of narrowing the gap between the life style in urban and rural areas. It can also be regarded as an extension of benefits deriving from national overall economic development to the rural folk. Lack of electricity will deprive enter populations of rural areas access to better living standards and will lead to social tensions and political instability.

In the last two decades, a lot of activities in the field of renewable energy have been taken to popularize modern RETs by different agencies and needed to be encouraged and continued. The Renewable Energy Programs of GS has become highly acclaimed among national and international policy makers, bilateral and multilateral development partners and by the RET enthusiasts. It is expected that the GEF funded "Rural Electrification and Renewable Energy Development Project" will also accelerate the growth of RETs utilization in the country.

RETs are slowly finding a niche market in Bangladesh. But still there are lots of barriers. However appropriate financing of this purchases is one of the key impediments to accelerate dissemination of renewable energy. In Bangladesh 44.3% people live in below poverty level and it is essential to create special subsidy for propagating RETs in their life. In addition careful attention should be paid to local customers, social hierarchy, discussion and technology training.

A gradual change from conventional energy to renewable energy would benefit both the economy and the nation as a whole. Time-bound targets for mass dissemination of different RET options have to be adopted by the GOB for fulfilling its obligation of universal electrification program by the year 2020.

The draft Renewable Energy Policy, submitted by the Power Cell, should be approved by the GOB immediately and REDA should be created to act as a focal point in the renewable energy sector of Bangladesh. REDA should be dedicated to renewable energy promotion, by supporting comprehensive economic energy analysis encouraging household sector to use renewable instead of conventional energy, managing and administering

credit funds and subsidies and also to remove the barriers prevailing in the renewable energy sector of the country. In other words, the overall objective of the REDA is to implement a national policy that will encompass the supply of adequate, reliable, sustainable and safe energy to all sectors of the national economy, by reducing our dependence on conventional energy and oil importation and consequently trade balance.

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